Ecosystem Considerations

2013
DRAFT

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Bering Sea, Aleutian Islands, and Gulf of Alaska

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Executive Summary of Recent Trends

Physical and Environmental Trends

- The state of the North Pacific atmosphere-ocean system during 2012-2013 reflected the combination of mostly near-neutral ENSO conditions and intrinsic variability (p. 20).
- Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific (p. 20,21).
- The Pacific Decadal Oscillation (PDO) has remained in a largely negative state since the latter part of 2007, and the North Pacific Gyre Oscillation has remained in a positive state during the same time period (p. 25).
- Models indicate a greater likelihood of near-neutral versus either El Niño or La Niña conditions for the winter of 2013-14 (p. 27).

Arctic

- There is reduced sea ice cover in the Arctic during the summer of 2013 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012 (p. 20).
- Ice concentrations in the Chukchi Sea have been observed to be greater during the summer of 2013 than in 2012 (p. 20).

Eastern Bering Sea

- The eastern Bering Sea shelf experienced less storminess than normal in fall 2012 and spring 2013. On the other hand, the weather during fall and winter was cold, which resulted in another relatively heavy ice year (p. 20).
- Oceanographic surveys of regions within the northern EBS between 2002-2012 have documented spatial variations in oceanographic characteristics (salinity, temperature, and zooplankton abundance). Norton Sound stands out as most distinct from other regions because of high surface and bottom temperatures, low surface and bottom salinities, and lower than average light transmission (p. 30)

Alaska Peninsula and Aleutian Islands

- Easterly wind anomalies prevailed in this region during the fall of 2012 and spring of 2013. Anomalies in this sense tend to enhance the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current (p. 20).

- A strong eddy developed south of Amukta Pass during summer 2012, indicating that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred during summer 2012 (p. 32).
- Eddy energy in the region has been low from the fall 2012 through early 2013, indicating that average volume, heat, salt, and nutrient fluxes were likely smaller during the period from spring 2010 until early spring 2012 (p. 32).
- Sea level pressure patterns indicated suppressed storminess. Sea surface temperatures appear to have been near normal during the past year (p. 21).

Gulf of Alaska

- The weather in this region included near normal air temperatures and below normal precipitation during fall 2012 to spring 2013 (p. 20).
- The mixed layer depths in the Gulf were slightly deeper than usual during the winter of 2012-2013 suggesting that the supply of nitrate to the euphotic zone for the spring bloom was also enhanced (p. 20).
- The winds during spring and summer 2013 were of the sense to favor more coastal upwelling than usual in the northern and eastern portions (p. 20).
- Eddy Kinetic Energy (EKE) levels in the western Gulf of Alaska were high in 2012 and 2013. Thus, phytoplankton biomass likely extended farther off the shelf in those years and cross-shelf transport of heat, salinity and nutrients were probably stronger (p. 34).
- In the northern Gulf, a spike of high EKE early in the year (February) was followed by low EKE from March through June 2013(p. 34).
- The 2012/2013 PAPA trajectory index was notable as ending up the furthest east among trajectories in recent years. However, the ending latitude was only somewhat southerly of the average ending latitude for all trajectories and certainly not atypical. This is consistent with the northeast Pacific wind forcing, which featured very strong westerly anomalies (p. 36).

Ecosystem Trends

Alaska-wide

- Total estimated seabird bycatch in all Alaskan groundfish fisheries in 2012 was 4,997 birds. This estimate is 40% below the running 5-year average for 2007-2011 of 8,295 birds (p. 78).
- Bycatch in the longline fishery showed a marked decline beginning in 2002 due to the deployment of streamer lines as bird deterrents. Since then, annual bycatch has remained below 10,000 birds, dropping as low as 3,704 in 2010. Numbers increased to 8,914 in 2011, the second highest in the streamer line era, but fell back to 4,544 in 2012 (p. 78).
- The apparent absence of any recent abrupt shifts in leading axes of basin-wide biological variability indicates a continuation of the northeast Pacific ecosystem states that have existed over recent decades (p. 83)

Arctic

Bering Sea

- Continuous plankton recorder observations indicated that the 2012 copepod community size anomaly was high in southern Bering Sea regions, indicative of cool conditions where subarctic species predominate. However, mesozooplankton biomass appeared to be low in 2012 (p. 47).
- During fall BASIS survey, total jellyfish biomass more than doubled in 2012 compared to 2011 and was the highest recorded biomass over the surveys. One station in the southern Bering Sea was responsible for half the total catch for the entire survey. This differs from 2010, when combined jellyfish species biomass also nearly doubled compared to the previous highs, but was spread out over the sampling grid (p. 42).
- Oceanographic surveys of the northern EBS during late summers from 2002-2012 have found highest abundances of large and small zooplankton in the South Bering Strait and North Inner regions, respectively, which coincides with the highest regions of juvenile salmon CPUE (p. 30)
- Young of year pollock energy density increased from values near 3.6 kJ/g in 2003-2005 to values near 5.0 kJ/g in 2008-2012. In 2012 the average energy content was low (6.52 kJ/fish) suggesting that the number of age-1 recruits per spawner should be below the overall median level in 2013 and the biomass of age-3 recruits should be less than median in 2015 (p. 51).
- Historically, Bristol Bay sockeye salmon runs have been highly variable, but in recent years, 2004-2010, runs have been well above the long term mean. The 2011 and 2012 runs of 31.9 and 29.1 million fish respectively, were closer to the long-term historical average (1963-2011) of 32.38 million fish. The run size forecasted for 2013 Bristol Bay sockeye is 26.03 million.
- The 2011 Temperture Change (TC) index value was slightly above the long term average, therefore slightly higher than average numbers of pollock are expected to survive to age-3 in 2013. In the future, the TC values in 2012 and 2013 indicate below average abundances of age-3 pollock in 2014 and above average abundances of age-3 pollock in 2015 (p. 71).

Aleutian Islands

Gulf of Alaska

- Icy Strait zooplankton density anomalies were strongly negative from 1997-2005, strongly positive in 2006-2009, and negative in 2010-2012. Total density showed little correspondence with annual temperature trends across years, with both positive and negative anomalies in both warm and cold years (p. 43).
- Icy Strait zooplankton were numerically dominated by calanoid copepods, including small and large species (long-term mean total density, 1997-2012) (p. 43).
- Lower trophic level productivity apparently increased in 2012 in the Alaskan Shelf region (northern GOA) in contrast to 2011. Copepod community size, mesozooplankton biomass, and large diatom abundance in 2012 all increased from 2011 levels (p. 47).
- The 2010 and 2011 mean abundance values of all ichthyoplankton taxa except rockfish (*Sebastes* spp.) deviated moderately from the long term survey means (p. 65).
- Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2012) median of 89,709 tons since 1998, and continues to be in 2012, an apparent decrease in biomass has been observed between 2011 and 2012. Notable drops in biomass were observed in Hoonah Sound and Sitka Sound (p. 55).

- Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts. Marine survival in 2010 (2008 brood year) was at an all-time high since 1977 but dropped in 2011 (p. 59).
- In addition to pink salmon CPUE, peak migration month, NPI, %pink in June-July trawl hauls, and the ADFG Escapement Index are significantly correlated with harvest and suggest a strong pink salmon harvest in 2013 (p. 62).
- Arrowtooth flounder, flathead sole, and other flatfish continue to dominate the catches in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to 2012 from years of record high catches seen from 2002 to 2005 (p. 74).

Fishing and Fisheries Trends

Alaska-wide

- With the Arctic FMP closure included, almost 65% of the U.S. EEZ of Alaska is closed to bottom trawling (p. 93).
- At present, no BSAI or GOA groundfish stock or stock complex is subjected to overfishing, and no BSAI or GOA groundfish stock or stock complex is considered to be overfished or to be approaching an overfished condition. The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in the tenth year of a 10-year rebuilding plan. Of the non-FSSI stocks, only the BSAI octopus complex is subject to overfishing, and none are overfished or approaching an overfished condition. (p. 122).
- The pattern of changes in the total number of vessels harvesting groundfish and the number of vessels using hook and line gear have been very similar since 1994. Numbers have generally decreased since 1994 but have remained relatively stable in the last 5 years (2008-2012). The total number of vessels was 1,518 in 1994 and 917 in 2012. Hook and line/jig vessels accounted for about 1,225 and 614 of these vessels in 1994 and 2012, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 182 in 2012. During the same period, the number of vessels using pot gear peaked in 2000 at 343, and decreased to 168 in 2012. (p. 129).

Bering Sea

- The maximum potential area of seafloor disturbed by trawling remained relatively stable in the 2000s, decreased in 2009-2010 and in 2012 returned to levels seen in the early 2000s (p. 97).
- Discarded tons of groundfish have continued a declining trend since 1994, but the 2012 values remained similar to 2011 (p. 88).
- Non-specified catch (Scyphozoan jellyfish, grenadiers and sea stars) comprised the majority of non-target catch during 1997-2012. The catch of non-specified species has decreased overall since the late 1990s. HAPC biota catch has remained stable since 2007. The catch of forage species decreased in 2008 and has remained generally low through 2012 (p. 89).

Aleutian Islands

- Discard rates have declined over the past nine years. Discards and discard rates are much lower now than they were in 1996 (p. 88).

- Non-specified catch (Scyphozoan jellyfish, grenadiers and sea stars) comprised the majority of non-target catch during 1997-2012. The non-specified catch declined from 2009 through 2011, then increased to its highest level in 2012, primarily due to grenadiers. HAPC catch has been variable over time in the AI and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Forage fish catches in the AI are minimal (p. 89).

Gulf of Alaska

- Discard rates in the Gulf of Alaska have varied over time but were lower than average in 2011 and 2012 (p. 88).
- Non-specified catch (Scyphozoan jellyfish, grenadiers and sea stars) comprised the majority of non-target catch during 1997-2012. The catch of non-specified species in the GOA has been generally consistent aside from a peak in 1998 and lows in 2009 and 2010. Sea anemones comprise the majority of the variable but generally low HAPC biota catch. The catch of forage species (primarily eulachon) decreased from 2011 to 2012 (p. 89).

Contents

* indicates contribution updated in 2013
† indicates new contribution
Editor's Note: Incomplete citations are marked with a ?, and will be finalized in the next draft.

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List of Figures

Responses to Comments from the Science and Statistical Committee (SSC)

December 2012 SSC Comments

The SSC appreciates the responsiveness of the authors to the 2011 SSC requests for improving the Ecosystem Considerations chapter. The chapter continues to improve in quality of presentation and relevance of the information presented. The reorganization of the presentations, both the "taxonomic order" and the subjects covered within the individual presentations on Ecosystem Status and Management Indicators, have improved the transfer of information. The inclusion of the Implications section is especially useful, though not all individual authors have done so. The start on the new Arctic section was excellent.

Thank you.

Two possible additional structural changes might be considered. For the reader to get the clearest view of the North Pacific as a whole as well as the four management regions under consideration (Gulf of Alaska, Aleutians, eastern Bering Sea, and Arctic), it might be helpful to separate the individual reports in the Ecosystem Status and Management Indicators section by management area. That would help the reader see the big picture for each area and would assist users in finding the indicator reports of greatest relevance to their needs.

We have considered this but decided against this structure as many of the individual reports in the Ecosystem Status and Management Indicators section cover multiple regions (e.g., Time Trends in Groundfish Discards (p. 88, Indicators of Basin-scale and Alaska-wide Community Regime Shifts (p. 83. Dividing these into separate reports would create redundancy. Instead, we hope that the continued development of the Ecosystem Assessment section, which is organized by region, will provide an overview of each region, with references to specific reports for greater detail.

A second structural change that would be helpful would be to develop brief, integrated, summaries of indices that are otherwise included in several reports. For example, the four reports on climate (Overland, Lauth, Eisner, and Bond) should be integrated. Similarly, the three reports that address flows into the Bering through the Aleutian Passes should be integrated and disparate findings resolved to reduce confusion. In another example, Bond suggests reduced flow because of westerly winds, Ladd suggests increased flow because of eddies to the south of Amukta Pass, and Laman's report on water temperatures in the Aleutians needs to address both of the forgoing to pull the picture together.

Likewise there are three reports on bottom temperatures on the eastern Bering Sea shelf that have some redundancies and call for a synthesis, as is also true for eastern Bering Sea zooplankton. If the individual report writers are unable to collaborate before turning in their report, perhaps the editor can add a brief synthesis after a group of reports on similar subjects to tie them together.

This year, we plan to add an Editor's Summary at the beginning of the sections (e.g., zooplankton, salmon) within the Ecosystem Status and Management Indicators that have multiple individual reports.

As the various indices become more established with solid time series behind them, effort should be made to test their skill in predicting recruitment, or forecast ecosystem responses.

We agree that this is important, and while we have not included this type of analysis within this draft, we hope to do so in the near future.

Where appropriate and possible, it would be useful to include error measures on all tables and graphs so the reader has a means of assessing the significance of the change being discussed (e.g., Fig. 38, Fig. 50, Table 4, Fig. 53, Fig., 54 [from 2012 report])

We have made extra effort to incorporate error estimates where appropriate.

Arctic Assessment: *Overall, this assessment is very well done, although brief. It will be important to develop additional ecosystem indicators: these could include data such as ice cover over the Chukchi and Beaufort seas shelves, George Divoky's information on black guillemots, a measure of subsistence hunter harvest rates and CPUE, the condition of polar bear and other harvested species.*

We will be providing an update to the preliminary Arctic assessment in the next draft.

Relative to the presentation given, the SSC notes that the unusual mortality event (UME) for marine mammals is more extensive than just walrus. Unusual skin lesions and lethargy have been noted in a variety of arctic marine mammals (seals, walrus, polar bears) and is an area of active investigation. In addition, as ice cover is reduced, many different populations of marine mammals will be impacted (e.g. walruses crowding together on shore, changes in whale abundance and distribution, potential impacts on ice seals). These potential impacts are driving petitions to list several species of ice seals.

The preliminary Arctic assessment included discussion of the unusual mortality event (UME) for both ice seals and walrus, but we were unaware of the impact on polar bears. If appropriate, we will provide an updated discussion in the preliminary Arctic assessment.

Eastern Bering Sea: *The section on the EBS is strong, but in several areas could be strengthened by integrating different data streams. For example, in the consideration of top-down effects, it may be time to begin modeling the potential impact of great whales on zooplankton and forage fish stocks, including age-0 and age-1 pollock.*

As stated above, we plan to add an Editor's Summary at the beginning of the sections (e.g., zooplankton, salmon) within the Ecosystem Status and Management Indicators that have multiple individual reports. With these summaries and the updated ecosystem assessments, we hope to provide integrated ecosystem information to the Council.

In discussing Bering Sea large zooplankton (page 10), there is no mention of Thermisto libellula.

What is the status of this amphipod, and what are implications of changes in its biomass, if any?

We have been in contact with the author and plan to provide Thermisto data in the next draft.

If the non-specified catch increase in the Bering Sea (page 14) is primarily due to increased catches of capelin and eulachon, is this the result of an increase in these species? Please tie in these findings with the forage fish CPUE, page 129, also mentioned on page 11 and 191.

We will address this comment in the next draft when we have updates to all of the report sections.

If there is a tie between forage fish abundance and mushy halibut syndrome in the Gulf of Alaska, is there any evidence of a connection between the survival of Chinook salmon in the Bering Sea and the distribution and/or abundance of forage fish there (page 54)? What might be the expected lag between a change in forage fish abundance and returns of Chinook to the Yukon River?

We will address this comment in the next draft when we have updates to all of the report sections.

On page 55, it is suggested to examine selected indices by domain. This seems like a good idea, if feasible. Given the upcoming synthesis of the Bering Sea Project, which will attempt to work at the level of the BEST/BSIERP areas, it might be good to see whether the scale at which they hope to work might be appropriate.

We will address this comment in the next draft when we have updates to all of the report sections.

On page 56, middle you refer to the need for research on the spatio-temporal distribution of Stellers sea lions and their prey. It would be good to include the spatio-temporal distribution of sea lion predators as well.

We will address this comment in the next draft when we have updates to all of the report sections.

On page 56, middle, would it be possible to use industry CPUE as an index of fishery performance?

We will address this comment in the next draft when we have updates to all of the report sections.

On page 111, the graph indicates very low primary production in the summer/fall of 2007. That was a particularly weak year-class of pollock, and can any synthesis be pulled together that would help tie together the events and findings for 2007? (see also page 115, 118, 129, 132).

We will address this comment in the next draft when we have updates to all of the report sections.

On page 194, the decrease in HAPC catch is discussed. Is it possible that the decrease is because of prior destruction of the HAPC? Relate to the catch of HAPC in the bottom trawl survey.

We will address this comment in the next draft when we have updates to all of the report sections.

Aleutian Islands: *In the western Aleutians dusky/rougheye rockfish are being caught in unusually high numbers (western ecoregion, hot topic, page 4). How does this relate to recent stock assessments for these fish in this area?*

We will address this comment in the next draft when we have updates to all of the report sections.

On page 62, where there is a recap of fish stocks in the Aleutians, it would be good to mention the status of cod. What is the role of cod in sea lion diets? Many years ago, cod may have been a *principal prey.*

We will address this comment in the next draft when we have updates to all of the report sections.

Page 64: Is there a time series of puffin chick survival or growth available? Prey switching without some independent measure of availability or abundance could mean the increase of prey a rather than the decrease of prey b.

We will address this comment in the next draft when we have updates to all of the report sections.

Gulf of Alaska: *The SSC looks forward to the development and inclusion of a Report Card section for the Gulf of Alaska.*

Once again we have had to postpone the development of a Gulf of Alaska report card and assessment due to staff loss. We hope to convene an assessment team in early 2014.

The SSC expressed concern about the AFSC GOA ichthyoplankton survey going from an annual effort to a biennial effort. Long-term (>25 years) continuous ichthyoplankton surveys are extremely rare, and effort should be made to ensure the survey continues at as frequent intervals as possible. The value of these studies of larval fish would be enhanced if there were some analyses of the relationships between larval abundance (and condition) and subsequent recruitment.

We will address this comment in the next draft when we have updates to all of the report sections.

On page 152, there is no mention of how well the index of larval abundance does at predicting recruitment. Ongoing evaluations of how predictions are performing over time are critical to continue. On page 173, is there any idea why there was a jump in the bycatch of seabirds 2011? Are the birds habituating to the streamers, and beginning to ignore them? Or is this due to increase in TAC? Scaling bycatch to hooks set might be useful.

We will address this comment in the next draft when we have updates to all of the report sections.

In the Gulf of Alaska, there has apparently been a decline in forage fish and an increase in mushy halibut syndrome. Forage fish are also prey for Chinook salmon. Can any connections among these three factors be identified? It would also be appropriate to examine how changes in the abundance of humpback whales and zooplankton may be impacting forage fish availability or abundance.

We will address this comment in the next draft when we have updates to all of the report sections.

Ecosystem Status and Management Indicators

Ecosystem Status Indicators

Indicators presented in this section are intended to provide detailed information and updates on the status and trends of ecosystem components. Older contributions that are not updated are excluded from this report. Please see archived versions available at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Physical Environment

North Pacific Climate Overview

Contributed by N. Bond (UW/JISAO))
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Last updated: August 2013

Summary: *The state of the North Pacific atmosphere-ocean system during 2012-2013 reflected the combination of mostly near-neutral ENSO conditions and intrinsic variability. The Aleutian low was weaker than usual in the winter of 2012-13, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and mostly warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a continuation of a negative sense to the Pacific Decadal Oscillation (PDO). The models used to forecast ENSO, as a group, are indicating a greater likelihood of near-neutral versus either El Niño or La Niña conditions for the winter of 2013-14.*

Regional Highlights:

Arctic. There is reduced sea ice cover in the Arctic during the summer of 2013 compared to seasonal norms, but not to the extent that occurred in 2011 and 2012. The ice edge was very near the shore for much of the Beaufort Sea as late as early August 2013, but is rapidly retreating at the time of this writing (14 August). Ice concentrations in the Chukchi Sea have been observed to be greater during the summer of 2013 than in 2012. In general, the sea ice of the Arctic is thinner than its long-term climatological mean, and so there is the potential for a relatively swift reduction in ice cover over the remainder of summer.

Bering Sea. The Bering Sea shelf also experienced less storminess than normal in fall 2012 and spring 2013. On the other hand, the weather during fall and winter was cold, which resulted in another relatively heavy ice year. The extent of this ice on this shelf appears to have been more variable than usual, with a series of advances and retreats. Based on previous observations, it can be expected that the cold pool was somewhat more extensive than usual during the summer of 2013, but that is uncertain (at the time of this writing) due to the reduction in hydrological survey data.

Alaska Peninsula and Aleutian Islands. - Easterly wind anomalies prevailed in this region during the fall of 2012 and spring of 2013. Anomalies in this sense tend to enhance the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. These periods also featured SLP patterns indicating suppressed storminess. There is relatively little direct monitoring of the physical oceanography of this region, but SST values (based in large part on remote sensing from satellites) appear to have been near normal during the past year.

Gulf of Alaska. The weather in this region included near normal air temperatures and below normal precipitation. The mixed layer depths in the Gulf were slightly deeper than usual during the winter of 2012-2013 suggesting that the supply of nitrate to the euphotic zone for the spring bloom was also enhanced. The winds during spring and summer 2013 were of the sense to favor more coastal upwelling than usual in the northern and eastern portions.

West Coast of Lower 48. This region experienced a relatively quiet winter, with less downwelling-favorable winds than normal, especially along the Oregon coast. The waters near the coast tended to be mostly cool and salty, with particularly low oxygen concentrations noted at depth during summer 2013. The cooler waters were accompanied by a greater preponderance of sub-arctic than sub-tropical zooplankton than usual in spring 2013 (B. Peterson, NOAA/NWFSC). For the spring and summer of 2013, the winds have tended to be more upwelling favorable than usual. Additional information on the state of the California Current system is available at `www.pacoos.org` and `http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/bb-midyear-update.cfm`.

Sea Surface Temperature and Sea Level Pressure Anomalies

Contributed by N. Bond (UW/JISAO))
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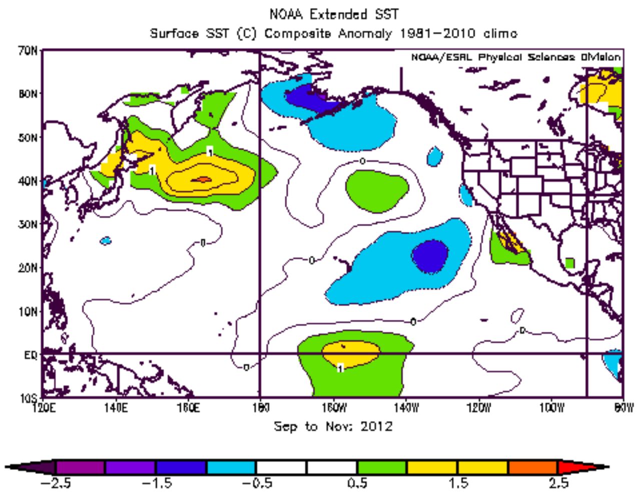
Contact: nicholas.bond@noaa.gov
Last updated: August 2013

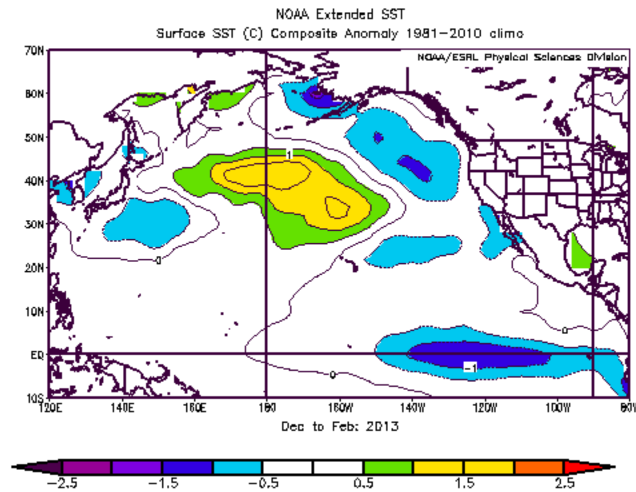
Description of indices: The state of the North Pacific from autumn 2012 through summer 2013 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps. The SST and SLP anomalies are relative to mean conditions over the period of 1981-2010. The SST data are from NOAA's Extended Reconstructed SST analysis; the SLP data are from the NCEP/NCAR Reanalysis project. Both data sets are made available by NOAA's Earth System Research Laboratory at `http://www.esrl.noaa.gov/psd/cgi-bin/data/`

`composites/printpage.pl`.

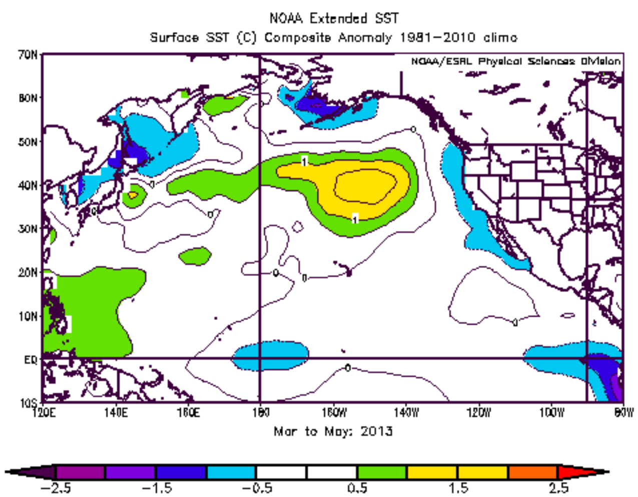
Status and trends: The climate forcing of the North Pacific during the year of 2012-13 began with a negative state for the PDO; the anomalies in the atmospheric forcing over the period considered here appears largely due to intrinsic variability. The tropical Pacific was warmer than normal during the autumn (Sep-Nov) of 2011 (Figure 1a) and a majority of forecast models at that time indicated the probable development of a weak-moderate El Niño for the following winter. This often causes anomalous warming in the waters along the west coast of North America and in the Bering Sea, which then were mostly cooler than normal. The pattern of anomalous SLP during autumn 2012 featured strongly positive anomalies over the Bering Sea extending across Alaska into northwestern Canada (Figure 2a). This pattern corresponds with easterly wind anomalies from roughly 40 ^{o} to 50 ^{o}N across most of the North Pacific, and was essentially opposite to that which occurred the year before in fall 2011.



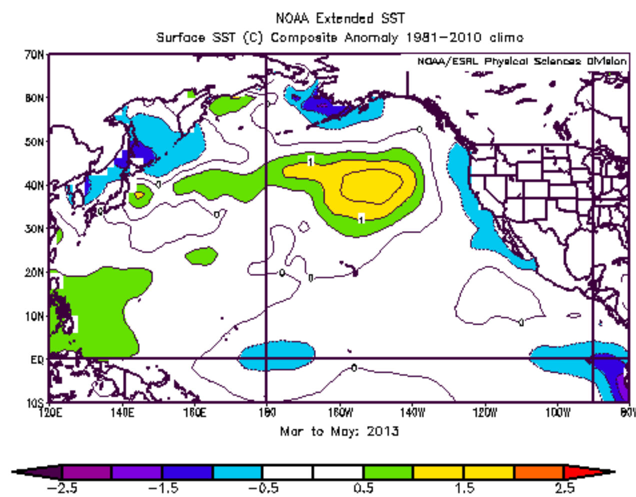
(a) Autumn



(b) Winter

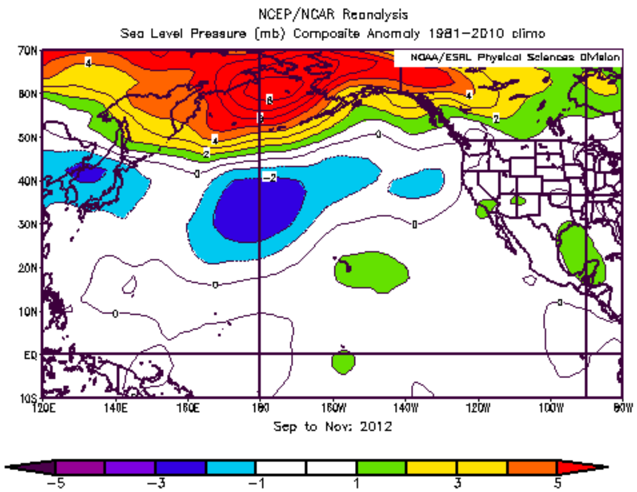


(c) Spring

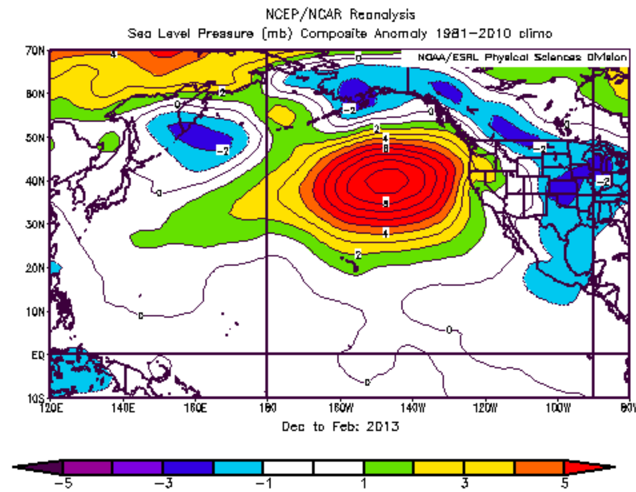


(d) Summer

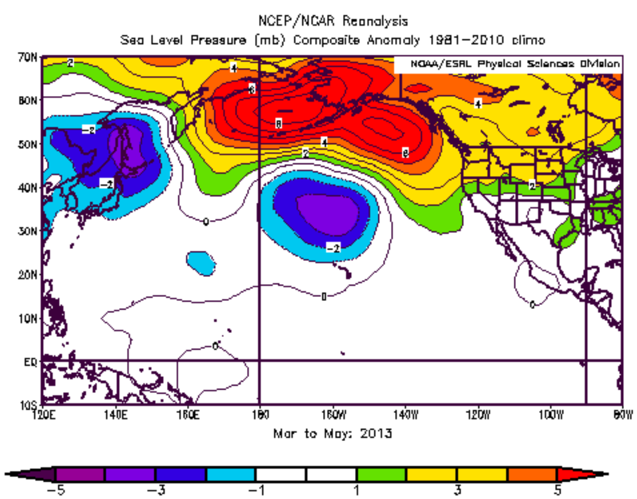
Figure 1: SST anomolies for autumn (September-November 2012), winter (December 2012 -February 2013), spring (March - May 2013), and summer (June - August 2013).



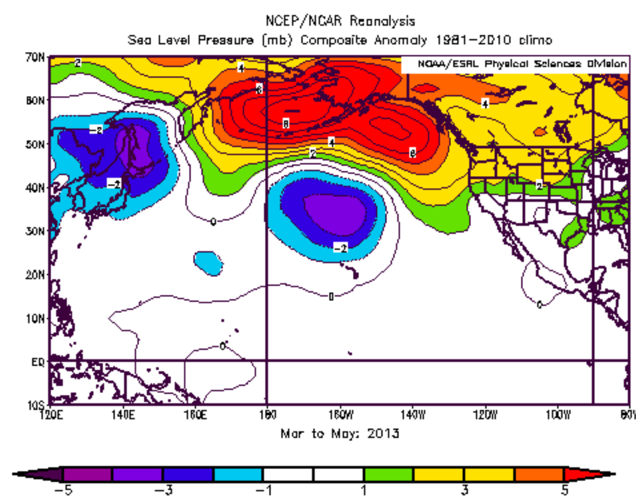
(a) Autumn



(b) Winter



(c) Spring



(d) Summer

Figure 2: SLP anomolies for autumn (September-November 2012), winter (December 2012 -February 2013), spring (March - May 2013), and summer (June - August 2013).

The pattern of anomalous SST in the North Pacific during winter (Dec-Feb) of 2012-13 (Figure 1b) resembled its counterpart during the previous fall. There was some modest cooling, relative to seasonal norms, in portions of the eastern North Pacific, and in the eastern tropical Pacific. The latter was insufficient to qualify as La Niña conditions. The anomalous SLP during winter 2012-13 was dominated by a large high (>10 mb) centered near 40 °N, 145 °W (Figure 2b). This anomaly pattern closely resembles that from a year ago. The anomalous SLP pattern shown in Figure 2b indicates westerly wind anomalies in the mean for the Gulf of Alaska and anomalous upwelling along the coast of California. For Alaskan waters, the SLP pattern promoted the delivery of cold air of Siberian origin to the Bering Sea and Gulf of Alaska; the higher than normal pressure west of California meant suppressed storminess in the far eastern North Pacific and below normal precipitation for the west coast of the lower 48 states.

The distribution of SST in spring (Mar-May) of 2013 (Figure 1c) indicates a continuation of colder than normal temperatures in the waters of the eastern Bering Sea and northwestern Gulf of Alaska waters and the development of anomalous warmth in the central North Pacific north of Hawaii. The SST anomalies in the tropical Pacific were generally weak, with more prominent anomalies developing in the far eastern portion off the coast of South America. The concomitant SLP anomaly map (Figure 2c) indicates a pattern closely resembling that of autumn 2012. This set-up implies suppressed storminess across the Bering Sea and Gulf of Alaska, and an early start to the upwelling season for the California Current System.

The pattern of anomalous SST in summer (Jun-Aug) 2013 (Figure 1d) featured the continued warming of the eastern North Pacific relative to seasonal norms. Positive anomalies developed along the coast of the northeastern portion of the Gulf of Alaska, and the eastern Bering Sea warmed to near-normal values. It remained slightly cooler than normal in the eastern tropical Pacific. The overall pattern represents a weakly negative expression of the Pacific Decadal Oscillation (PDO), as further discussed below. The distribution of anomalous SLP (Figure 2d) included a continuation of positive anomalies stretching from the eastern Bering Sea across the Gulf of Alaska into Canada. The associated wind anomalies from the east in the eastern North Pacific between about 35° and 45° N meant poleward Ekman transport anomalies, which is consistent with the warming in the same region. The gradients in the SLP anomalies along the west coast of North America supported slightly greater than normal upwelling in the southeast Gulf of Alaska and relatively weak upwelling along California. This result is for the summer months as a whole; the SLP and wind anomaly patterns in the eastern North Pacific during July and August were almost mirror images of one another.

Climate Indices

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Description of indices: Climate indices provide a complementary perspective on the North Pacific atmosphere-ocean climate system to the SST and SLP anomaly maps presented above. The focus here is on five commonly used indices: the NINO3.4 index to characterize the state of the El Niño/Southern Oscillation (ENSO) phenomenon, Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2003 through early summer 2013 are plotted in Figure 3.

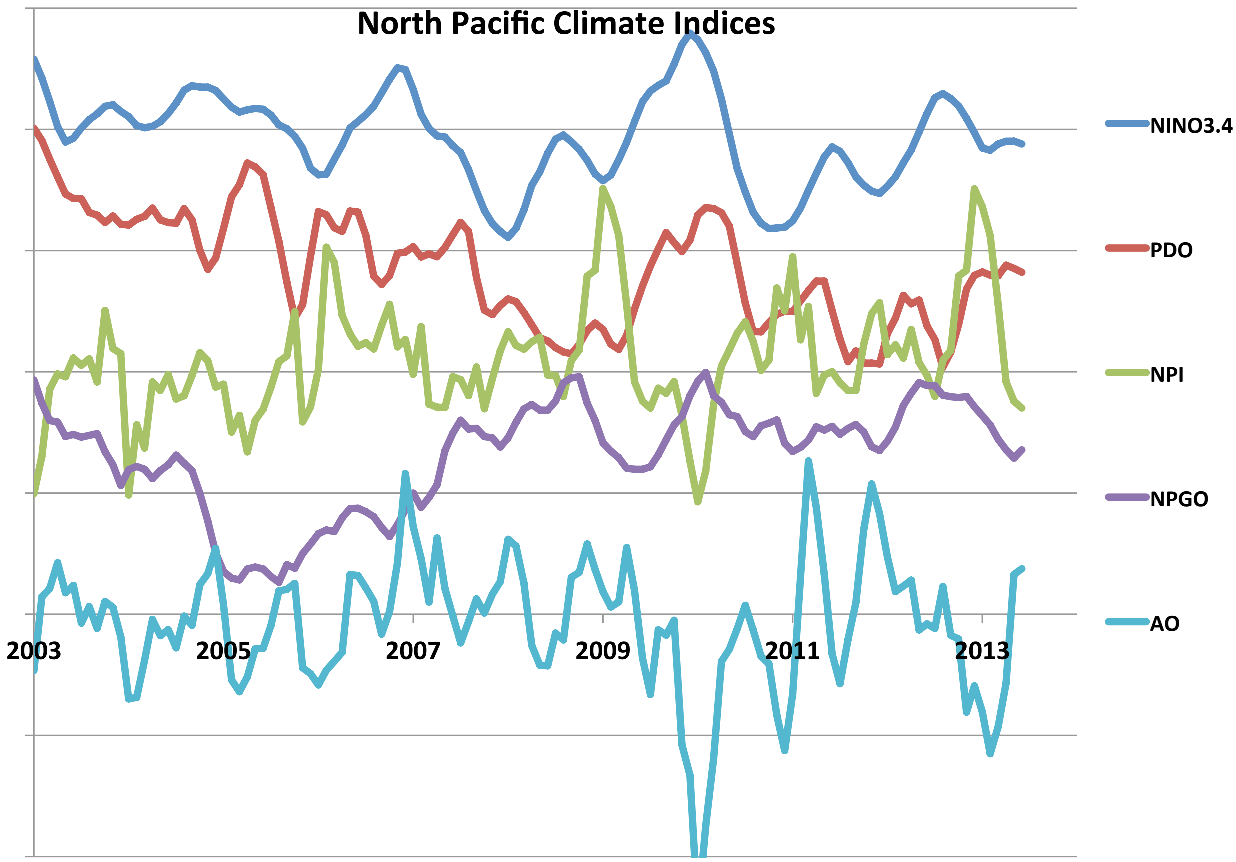

Figure 3: Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 2 standard deviations. More information on these indices is available from NOAA's Earth Systems Laboratory at `http://www.esrl.noaa.gov/psd/data/climateindices`.

Status and trends: Climate indices provide a complementary perspective on the North Pacific atmosphere-ocean climate system to the SST and SLP anomaly maps presented above. The focus here is on five commonly used indices: the NINO3.4 index to characterize the state of the El Nio/Southern Oscillation (ENSO) phenomenon, Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2003 through early summer 2013 are plotted in Figure 3.

The state of the North Pacific atmosphere-ocean system reflected intrinsic variability during 2012-13. The NINO3.4 index was weakly positive in the fall of 2012, and has been slightly negative since late 2012. The small magnitude of this signal implies a near-neutral state for ENSO, and hence the tropical Pacific is unlikely to have contributed significantly to the perturbations in the climate of the North Pacific that have occurred over the last year. The overall positive trend in the NINO3.4

index is consistent with a positive trend in the PDO in the last year or so. The PDO has been in a largely negative state since the latter part of 2007; it is uncertain whether the recent tendency of an upward trend in the PDO will persist, or whether it will revert back to negative values. The NPI was strongly positive (implying a weak Aleutian Low) during the winter of 2012-2013. This often occurs in association with La Niña, but as mentioned above, was not the case in this instance.

The North Pacific Gyre Oscillation (NPGO) represents the second leading mode of variability for the North Pacific, and has been shown to relate to chemical and biological properties in the Gulf of Alaska and the southern portion of the California Current (Di Lorenzo et al., 2008, 2009). It has been in a positive state since 2007, which projects on stronger than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current. The AO represents a measure of the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic, at a latitude of roughly 45 ^{o} N. It has a weakly positive correlation with sea ice extent in the Bering Sea. During periods of positive AO, cold air outbreaks to mid-latitudes are suppressed. The AO was strongly negative during the winter of 2012-13. That has been the case during three out of the last 4 winters, with 2011-12 being the exception. It has been suggested that the declines in sea ice coverage in the Arctic in fall may be responsible, in part, for the recent tendency for the AO to be negative in the following winter season. This is a matter of considerable controversy and interest to the polar climate community.

Seasonal Projections from the National Centers for Environmental Prediction (NCEP)

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Description of index: Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figures 6a-c. The uncertainties and errors in the predictions from any single climate model can be substantial. An ensemble approach incorporating different models is particularly appropriate for seasonal and longer term simulations; the NMME represents the average of 6 models. More detail on the NMME, and projections of other variables, are available at the following website: `http://www.cpc.ncep.noaa.gov/products/NMME/`. Seasonal projections from the NCEP coupled atmosphere-ocean forecast system model (CFS) for SST are shown in Figure 4.

Status and trends: These NMME forecasts of 3-month average SST anomalies indicate warming in the central North Pacific between the Hawaiian Islands and Alaska into fall (Sep-Nov 2013) and a continuation of slightly cooler water than normal in the northeastern Bering Sea (Figure 4a). This overall pattern is maintained, with some weakening in magnitude, through the 3-month periods of November 2013 - January 2014 (Figure 4b) and January 2014 - March 2014 (Figure 4c). In an overall sense, these patterns project onto a negative sense for the PDO, largely because of the relatively warm anomalies near the dateline. The NMME forecasts also include a slight warming in the tropical Pacific, especially in the western portion. The ensemble mean values of these anomalies are too weak to qualify as El Niño, but it is still possible that an ENSO event (probably of modest amplitude at best) could develop. At the time of this writing (early August 2013) the probabilistic forecast provided by NOAA's Climate Prediction Center (CPC) in collaboration with the International Research Institute for Climate and Society (IRI) for the upcoming fall through spring is a slightly greater than 50% chance for a near-neutral state for ENSO and roughly equal and lesser odds of El Niño or La Niña. It bears noting the NMME projections are suggesting the continuation of rather cold upper ocean temperatures for most Alaskan waters. It is emphasized that the skill in these projections is limited. For example, during August 2012 there were strong indications of warming in the tropical Pacific, and concomitant effects on the North Pacific climate, that did not materialize.

Implications Based on not just the SST predictions shown in Figure 4, but also other forecast fields, it is likely that there will be a warming of Alaskan waters over the next 2-3 seasons, relative to the mostly cooler than normal temperatures that have prevailed over the last 5 years.

Eastern Bering Sea

Eastern Bering Sea Climate - FOCI

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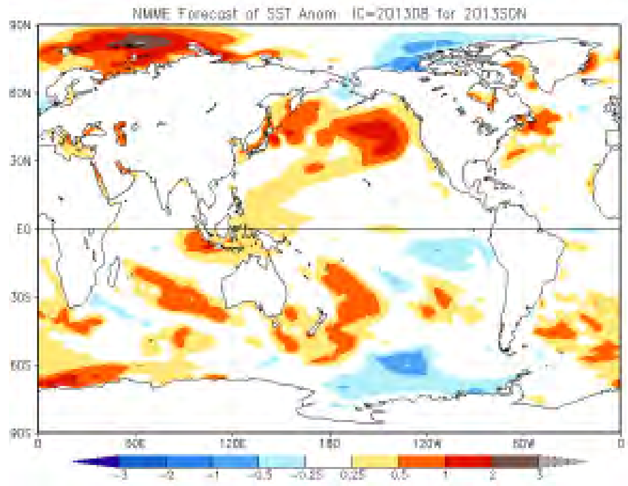
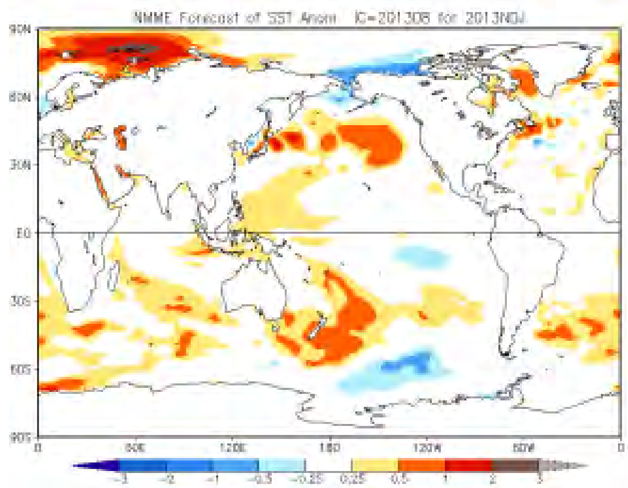
Last updated September 2012

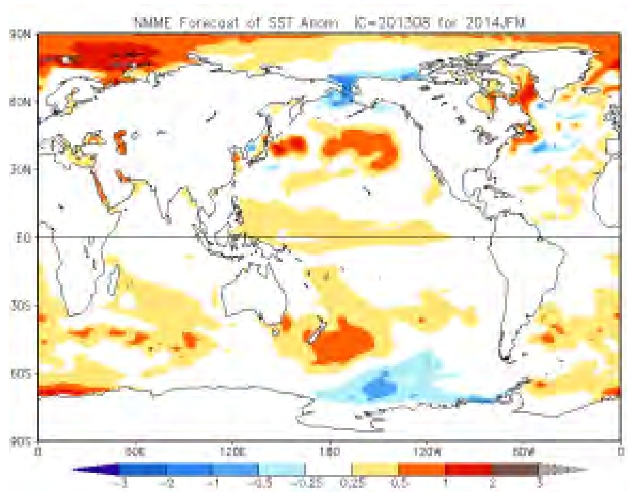
See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`



(a) Months SON



(b) Months NDJ



(c) Months JFM

Figure 4: Three-month forecasts of SST anomalies from the NMME model for SON, NDJ, and JFM of the 2013-2014 cool season.

Summer Bottom and Surface Temperatures - Eastern Bering Sea

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Regional Water Mass Characteristics in the Northern Bering Sea

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Description of index: The oceanography and shelf dynamics of the southern eastern Bering Sea (EBS) have been well-studied, while less attention has been given to the northern EBS, although commercially important fisheries are present in both the south and the north. Sea ice extent and duration, and freshwater inputs from the Yukon River are substantially higher in the north compared to the south, resulting in large variations in oceanography between the northern and southern EBS and between regions within the northern EBS. We describe spatial variations in oceanographic characteristics (salinity, temperature, and zooplankton abundance) for pre-defined regions (Figure 5) (Ortiz et al., in press), and compare these characteristics to juvenile salmon biomass (all species combined) in the northern EBS.

Sampling was conducted on a station grid using a CTD (SBE 19, 25 or 9-11) equipped with a Wet Labs fluorometer, and beam transmissometer. The survey grid (60 km station spacing) encompassed areas between 60° and 65° N latitude over the EBS shelf. Sampling took place during Aug.-Oct., 2002-2011. Zooplankton were collected over the water column: large taxa ($>505\mu$m) with oblique bongo-net tows (505 μm) and small taxa ($<505\mu$m) with a vertical Juday-net tow (168 μm). Samples were preserved in 5% formalin and enumerated at shore based facilities. Juvenile salmon were caught with a surface rope trawl (Can trawl model 400-580 spread 60 m (width) by 15 m (depth)), towed 30 min at 3.5 to 5 knots. Salmon weights were measured for each species (chum, pink, chinook, coho, sockeye), and the multispecies biomass catch per unit effort (CPUE) was estimated for all species combined. Bering Sea Integrated Ecosystem Research Program (BSIERP) region delineations were drawn by consensus across researchers based on observed oceanography, bathymetry, benthic fauna, fish, seabird and marine mammal distribution (Ortiz et al., in press). Data were broken out by BSIERP region for primary investigations. Some BSIERP regions were combined to investigate temporal trends (2002-2011) in parameters (salinity, temperature, large and small zooplankton abundance, and juvenile salmon biomass), with the combined North Inner and South Bering Strait regions (NI-SBS), and the combined North Middle and St. Mathews regions (NM-SM).

Status and trends: Norton Sound stands out as a distinct region within the northern EBS characterized by high surface and bottom temperatures, low surface and bottom salinities, and

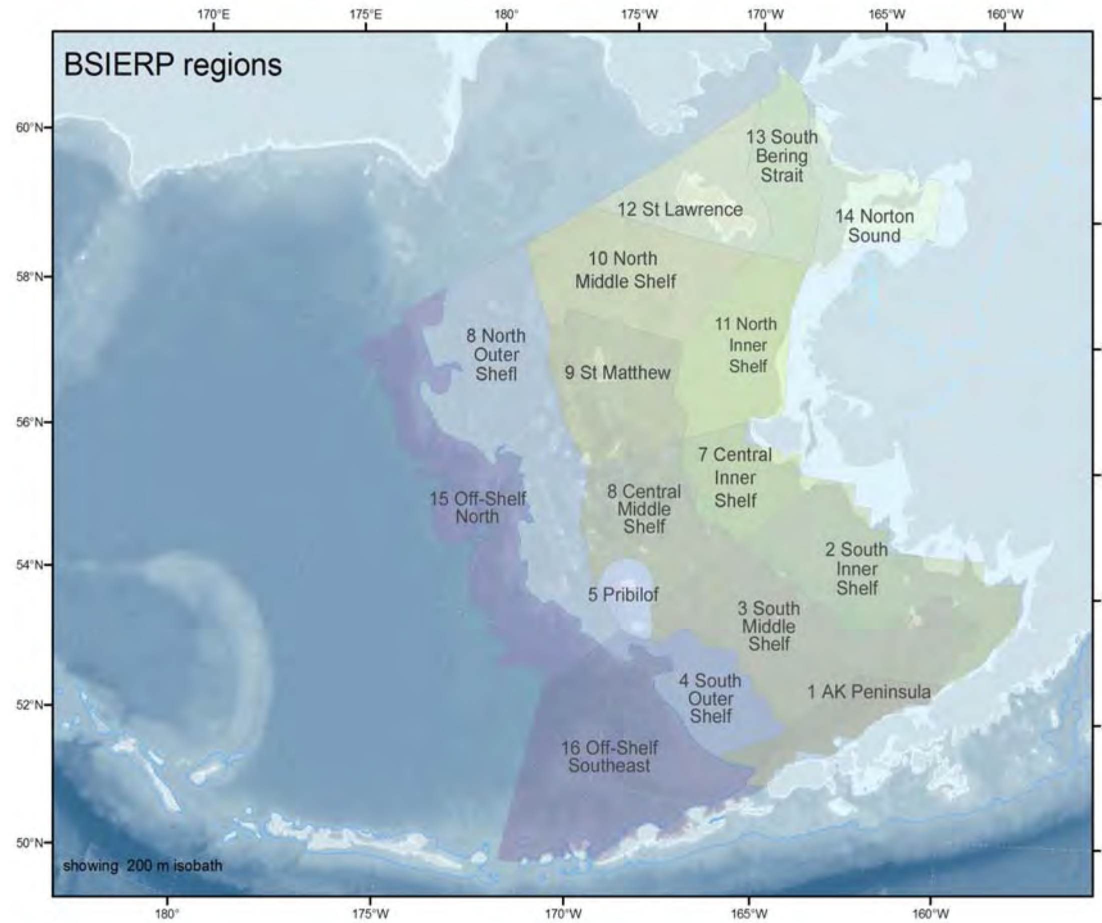

Figure 5: Bering Sea Integrated Ecosystem Research Program (BSIERP) regions from Ortiz et al. (in press)

lower than average light transmission (Table 1). . The South Bering Strait and North Inner regions are areas of high juvenile salmon biomass, as well as high numbers of large zooplankton (S Bering Strait) and high numbers of small zooplankton (N Inner). Highest light transmission values are seen with high bottom and surface salinity in the St. Lawrence region, while low transmission values are found with low bottom and surface salinity in Norton Sound. Analysis of yearly trends revealed a positive relationship between surface salinity and large zooplankton abundance (NI-SBS) until 2009-2010. There is a negative relationship between large and small zooplankton for NI-SBS, while a positive relationship is seen in NM-SM. Juvenile salmon biomass for NI-SBS increased in years with colder saltier bottom waters. In contrast, salmon biomass for NM-SM increased in years with warmer bottom temperatures.

Factors influencing observed trends: Initial findings reveal connections between juvenile salmon and bottom temperature, bottom salinity, and large and small zooplankton, depending on the region. Surface temperature and salinity changes over the northern EBS can change considerably from season to season, and from near to offshore. Ice melt and high fresh water run-off contribute to the low salinities in Norton Sound. Shallow depths contribute to higher temperatures in summer/early fall. Norton Sound has relatively low juvenile salmon biomass during late sum-

Table 1: Oceanographic parameters, large and small zooplankton abundance and juvenile salmon biomass by BSIERP region. Boldface indicates high/maximum values, and italics indicate minimum values.

BSIERP region	Temp Top (°C)	Temp Bottom (°C)	Salinity Top	Salinity Bottom	Trans-mission (% light trans)	Large Zoop Abund. (# m-3)	Small Zoop Abund. (#/m^{-3})	Juvenile salmon biomass (kg km^{-2})
North Inner	8.25	6.53	30.63	30.92	82	84	**104,127**	**3,706**
North Middle	7.83	1.26	31.15	31.57	83	90	54,969	819
Norton Sound	**9.70**	**8.92**	*27.00*	*28.29*	*65*	41	13,037	575
South Bering Strait	7.51	5.15	31.11	31.59	82	**2,418**	10,399	**2,287**
St. Lawrence	7.65	2.97	31.80	32.20	89	183	13,108	194
St. Matthews	7.61	1.33	31.32	31.74	84	67	5,941	930

mer/early fall, while highest juvenile salmon biomass is found in South Bering Strait and North Inner regions. Future analysis will focus on individual salmon species while investigating their spatial and temporal relationships with oceanographic parameters.

Implications: The highest abundances of large and small zooplankton were seen in the South Bering Strait and North Inner regions, respectively, which coincided with the two highest regions of juvenile salmon CPUE. Thus, large zooplankton could be important prey for juvenile salmon in the South Bering Strait region, while small zooplankton could be important prey for juvenile salmon in the North Inner region.

Aleutian Islands

Eddies in the Aleutian Islands - FOCI

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Description of index: Eddies in the Alaskan Stream south of the Aleutian Islands have been shown to influence flow into the Bering Sea through the Aleutian Passes (Okkonen, 1996). By influencing flow through the passes, eddies could impact flow in the Aleutian North Slope Current and Bering Slope Current as well as influencing the transports of heat, salt and nutrients (Mordy et al., 2005; Stabeno et al., 2005) into the Bering Sea.

Since 1992, the Topex/Poseidon/Jason/ERS satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (Ducet et al., 2000). Eddy kinetic energy (EKE) calculated from gridded altimetry data is particularly high in the Alaskan Stream from Unimak Pass to Amukta Pass (Figure 6) indicating the occurrence of frequent, strong eddies in the region. The average EKE in the region 171°W-169°W, 51.5°-52.5°N (Figure 7) provides an index of eddy energy likely to influence the flow through Amukta Pass. Numerical models have suggested that eddies passing near Amukta Pass may result in increased flow from the Pacific to the Bering Sea (Maslowski et al., 2008). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

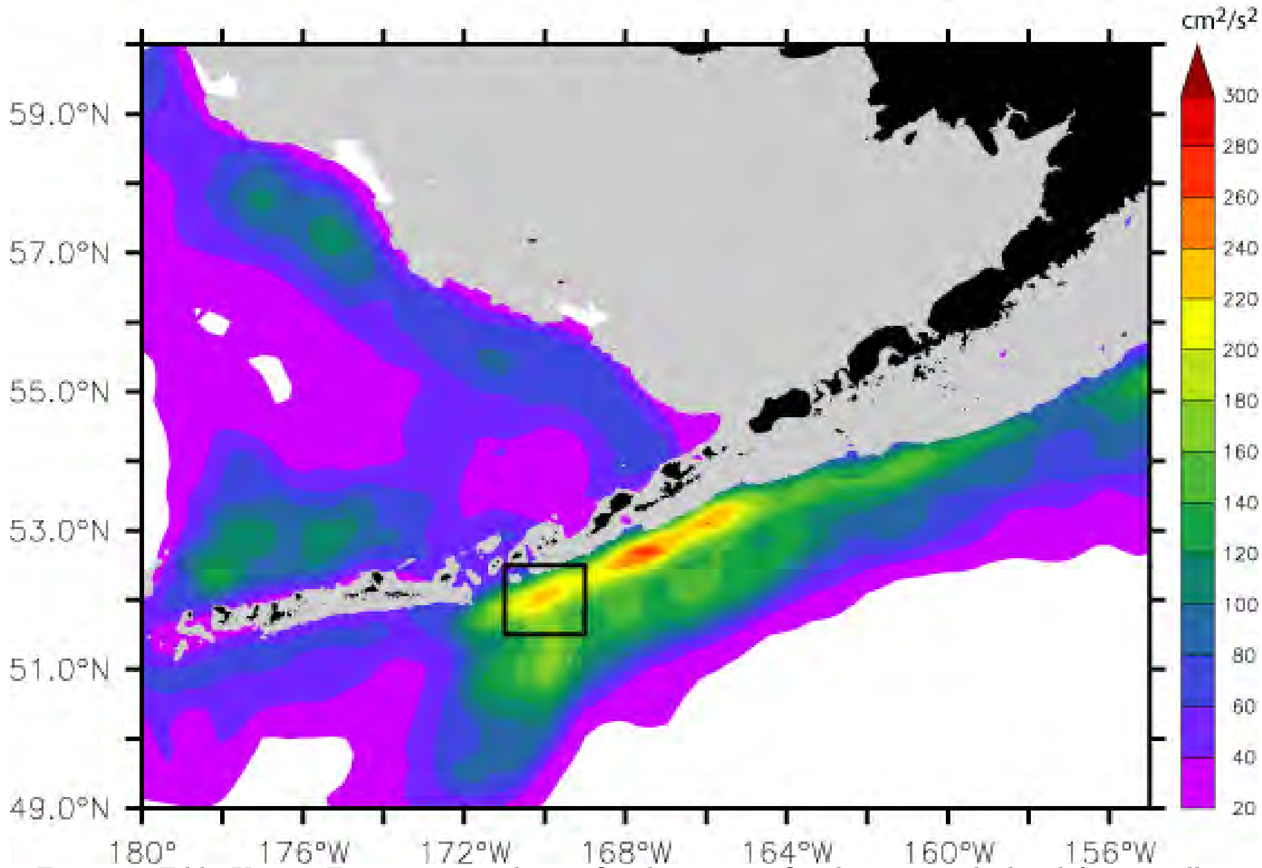

Figure 6: Eddy Kinetic Energy averaged over October 1993 - October 2012 calculated from satellite altimetry. Square denotes region over which EKE was averaged for Figure 7.

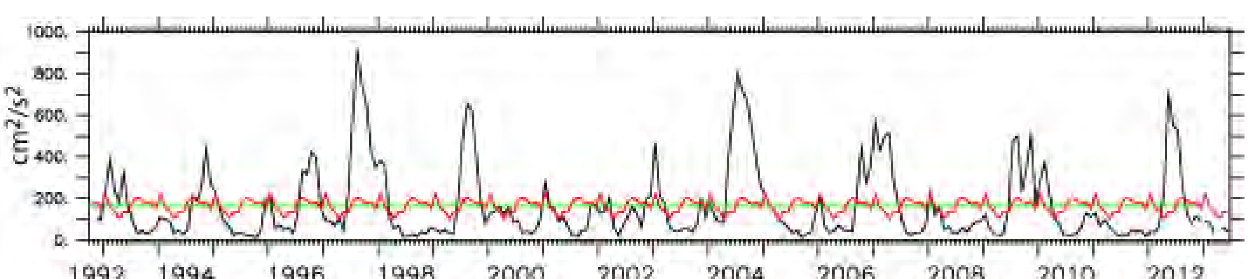

Figure 7: Eddy kinetic energy (cm^2 s^{-2}) averaged over region shown in Figure 6. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product). Red: seasonal cycle. Green (straight line): mean over entire time series.

Status and trends: Particularly strong eddies were observed south of Amukta Pass in 1997/1998, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. Eddy energy in the region has been low from the fall 2012 through early 2013.

Factors causing trends: The causes of variability in EKE are currently unclear and a subject of ongoing research.

Implications: These trends indicate that higher than average volume, heat, salt, and nutrient fluxes to the Bering Sea through Amukta Pass may have occurred in 1997/1998, 1999, 2004, 2006/2007, 2009/2010, and summer 2012. These fluxes were likely smaller during the period from fall 2012 until early 2013.

Water Temperature Data Collections - Aleutian Islands Trawl Surveys

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See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Gulf of Alaska

Eddies in the Gulf of Alaska - FOCI

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Description of index: Eddies in the northern Gulf of Alaska have been shown to influence distributions of nutrients (Ladd et al., 2009, 2005, 2007), phytoplankton (Brickley and Thomas, 2004) and ichthyoplankton (Atwood et al., 2010), and the foraging patterns of fur seals (Ream et al., 2005). Eddies propagating along the slope in the northern and western Gulf of Alaska are generally formed in the eastern Gulf in autumn or early winter (Okkonen et al., 2001). Using altimetry data from 1993 to 2001, Okkonen et al. (2003) found that strong, persistent eddies occur more often after 1997 than in the period from 1993 to 1997. Ladd (2007) extended that analysis and found that, in the region near Kodiak Island (Figure 8; Region c, eddy energy in the years 2002-2004 was the highest in the altimetry record.

Since 1992, the Topex/Poseidon/Jason/ERS satellite altimetry system has been monitoring sea surface height. Eddy kinetic energy (EKE) can be calculated from gridded altimetry data (merged TOPEX/Poseidon, ERS-1/2, Jason and Envisat; (Ducet et al., 2000), giving a measure of the mesoscale energy in the system. A map of eddy kinetic energy in the Gulf of Alaska averaged over the altimetry record (updated from Ladd (2007)) shows four regions with local maxima (labeled a, b, c and d in Figure 8). The first two regions are associated with the formation of Haida (a) and Sitka (b) eddies. Eddies that move along the shelf-break often feed into the third and fourth high EKE regions (c and d; Figure 8). By averaging EKE over regions c and d (see boxes in Figure 8), we obtain an index of energy associated with eddies in these regions (Figure 9). The altimeter products were produced by the CLS Space Oceanography Division (AVISO, 2012).

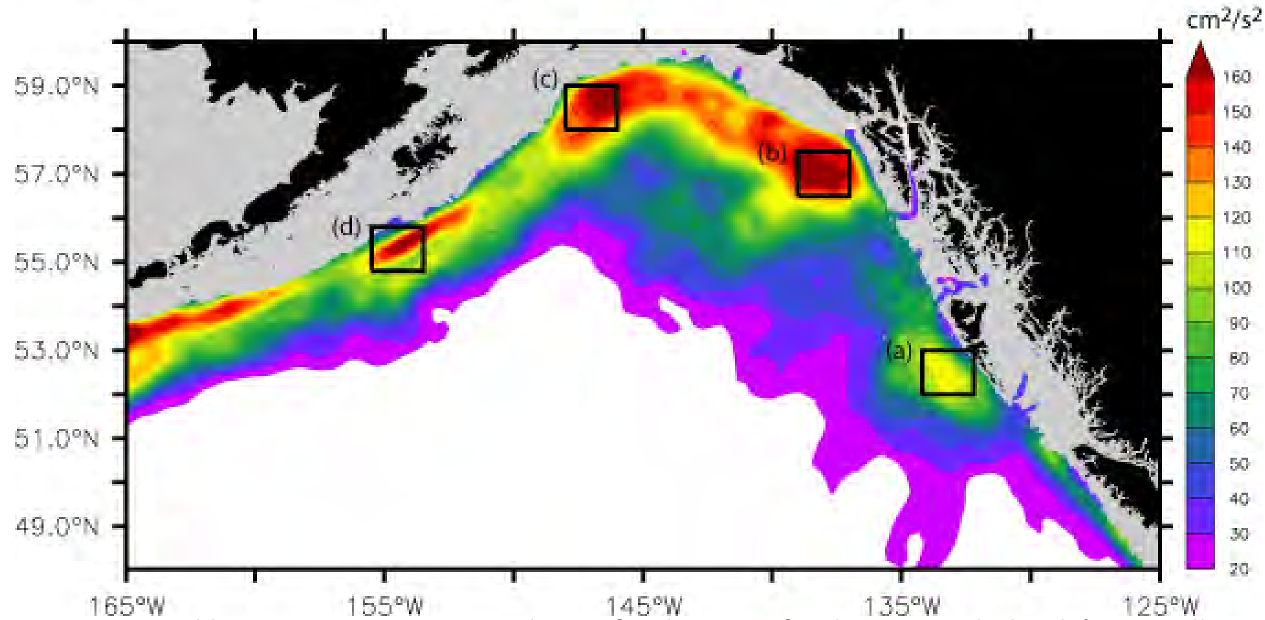

Figure 8: Eddy Kinetic Energy averaged over October 1993-October 2011 calculated from satellite altimetry. Regions (c) and (d) denote regions over which EKE was averaged for Figure 9.

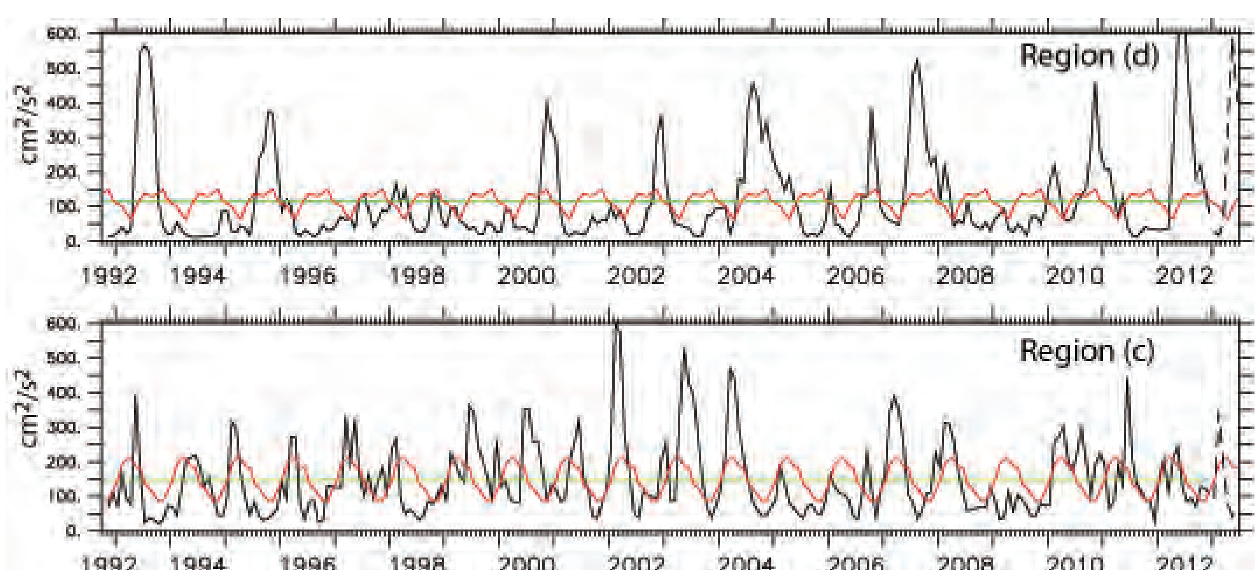

Figure 9: Eddy kinetic energy (cm^2 s^{-2}) averaged over Region (d) (top) and Region (c) (bottom) shown in Figure 8. Black (line with highest variability): monthly EKE (dashed part of line is from near-real-time altimetry product which is less accurate than the delayed altimetry product), Red: seasonal cycle. Green (straight line): mean over entire time series.

Status and trends: The seasonal cycle of EKE averaged over the two regions (c and d) are out of phase with each other. Region (c) exhibits high EKE in the spring (March-May) and lower EKE in the autumn (September-November) while region (d) exhibits high EKE in the autumn and low EKE in the spring. EKE was particularly high in region (c) in 2002-2004 when three large persistent eddies passed through the region. In region (d), high EKE was observed in 1993, 1995, 2000, 2002, 2004, 2006, 2007, 2010, 2012, and 2013. In region (c), a spike of high EKE early in the year (February) was followed by low EKE from March through June 2013. The summer 2013 EKE is calculated from near-real-time altimetry data which has lower quality than the delayed time data and may be revised.

Factors causing observed trends: In the eastern Gulf of Alaska, interannual changes in surface winds (related to the Pacific Decadal Oscillation and El Niño) modulate the development of eddies (Combes and Di Lorenzo 2007). In the western Gulf of Alaska, variability is related both to the propagation of eddies from their formation regions in the east and to intrinsic variability.

Implications: EKE may have implications for the ecosystem. Phytoplankton biomass was probably more tightly confined to the shelf during 2009 due to the absence of eddies, while in 2007, 2010, 2012 and 2013 (region (d)), phytoplankton biomass likely extended farther off the shelf. In addition, cross-shelf transport of heat, salinity and nutrients were probably weaker in 2009 than in 2007, 2010, 2012 and 2013 (or other years with large persistent eddies). Eddies sampled in 2002-2004 were found to contain different ichthyoplankton assemblages than surrounding slope and basin waters indicating that eddies along the slope may influence the distribution and survival of fish (Atwood et al., 2010). In addition, carbon isotope values suggest that cross-shelf exchange due to eddies may be important to the marine survival rate of pink salmon (Kline, 2010).

Ocean Surface Currents - Papa Trajectory Index

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Last updated: August 2012

Description of index: The PAPA Trajectory Index (PTI) provides an annual index of near-surface water movement variability, based on the trajectory of a simulated surface drifter released at Ocean Station PAPA (50°N, 145°W; Figure 10). The simulation for each year is conducted using the "Ocean Surface CURrent Simulator" (OSCURS; `http://las.pfeg.noaa.gov/oscurs`). Using daily gridded atmospheric pressure fields, OSCURS calculates the speed and direction of water movement at the ocean's surface at the location of a simulated surface drifter. It uses this information to update the position of the simulated drifter on a daily basis over a specified time period. For the index presented here, OSCURS was run for 90 days to simulate a surface drifter released at Ocean Station PAPA on December 1 for each year from 1901 to 2012.

Status and trends: In general, the trajectories fan out northeastwardly toward the North American continent (Figure 10). The 2009/2010 trajectory was an exception and resulted in the westernmost trajectory endpoint for the entire set of model runs (1902-2012). This trajectory is, however, consistent with the atmospheric conditions that existed during the winter of 2009-2010 (N. Bond,

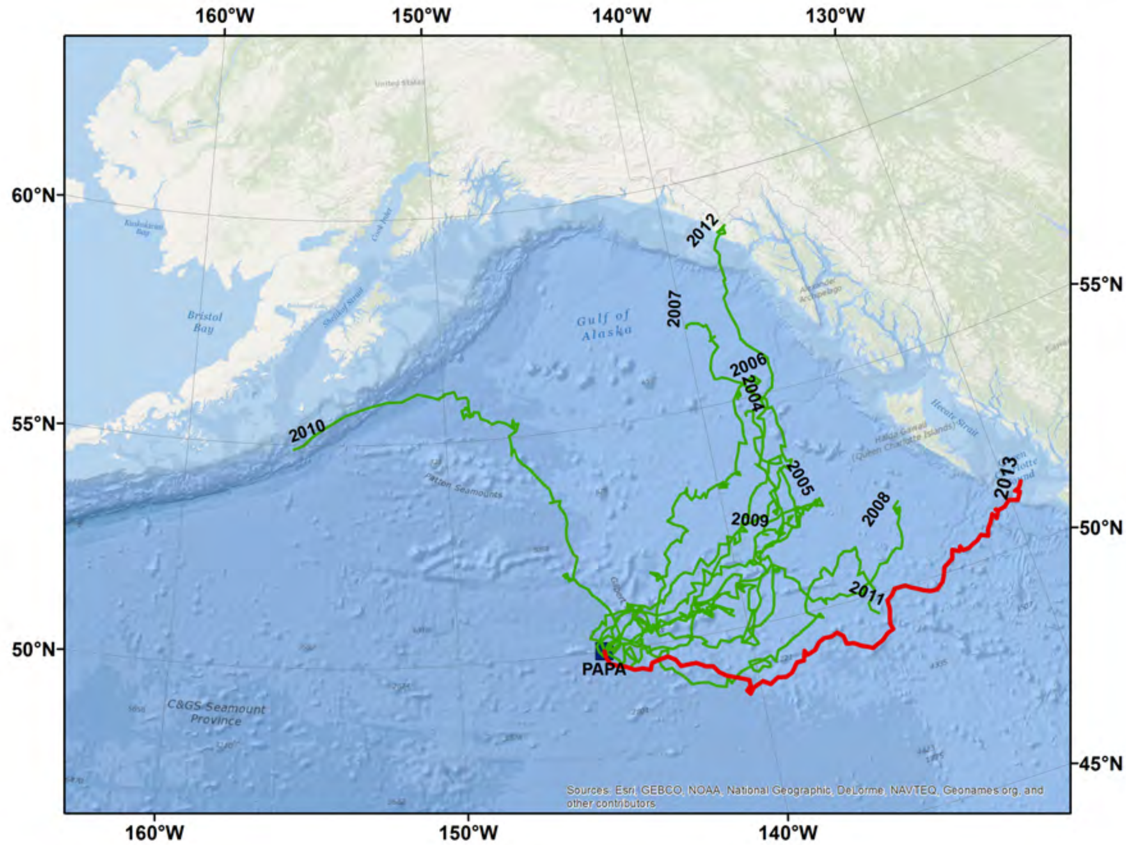

Figure 10: Simulated surface drifter trajectories for winters 2004-2013 (endpoint year). End points of 90-day trajectories for simulated surface drifters released on Dec. 1 of the previous year at Ocean Weather Station PAPA are labeled with the year of the endpoint (50°N, 145°W).

pers. comm.). Under the influence of contemporaneous El Niño conditions, the Aleutian Low in the winter of 2009-2010 was anomalously deep and displaced to the southeast of its usual position in winter (Bond and Guy, 2010), resulting in anomalously high easterly (blowing west) wind anomalies north of Ocean Station PAPA. The 2011/2012 trajectory followed the general northeastwardly path of most drifters, but was notable because its ending latitude was the northernmost of all trajectories since 1994. The 2012/2013 trajectory was notable as ending up the furthest east among trajectories in recent years. However, the ending latitude was only somewhat southerly of the average ending latitude for all trajectories (Figure 11) and certainly not atypical. This is consistent with the northeast Pacific wind forcing, which featured very strong westerly anomalies (see the sea level pressure (SLP) anomaly map p.24).

The PTI time series (Figure 11, black dotted line and points) indicates high interannual variation in the north/south component of drifter trajectories, with an average between-year change of >4° and a maximum change of greater than 13o (between 1931-1932). The change in the PTI between 2010/2011 and 2011/2012 was the largest since 1994, while the change between 2011/2012

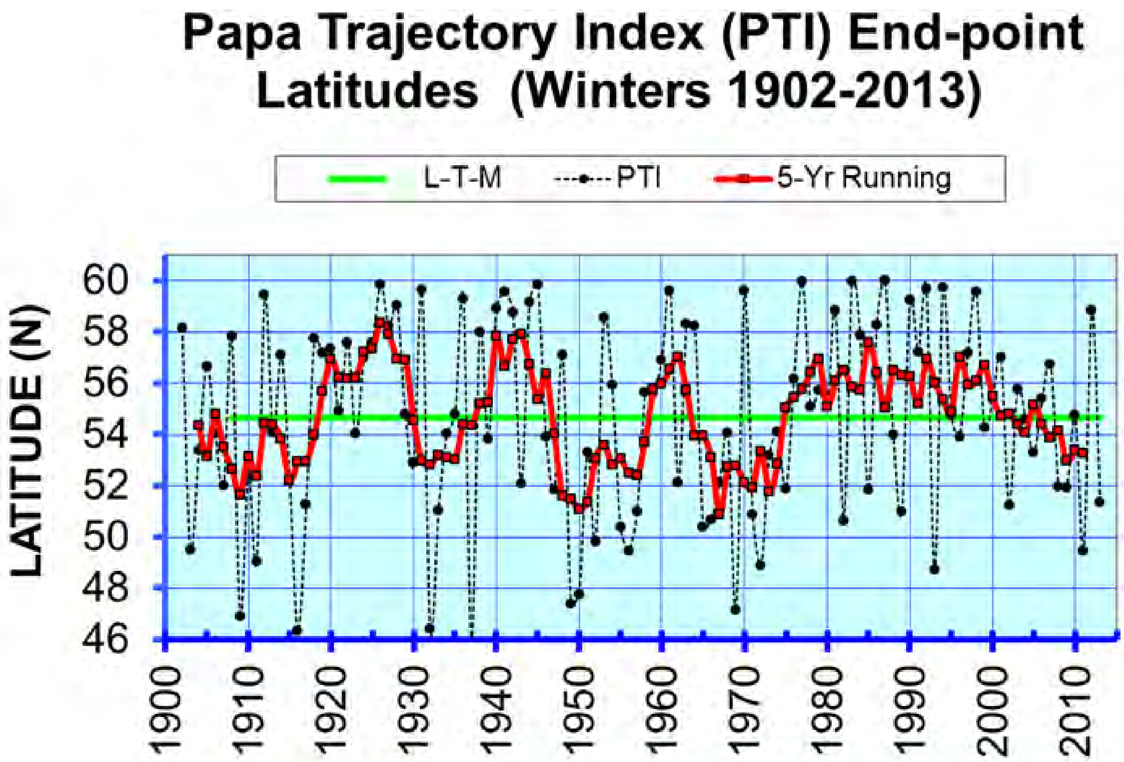

Figure 11: Annual, long-term mean (green line) and 5-year running mean (red line and squares) of the PAPA Trajectory Index time-series (dotted black line and points) for 1902-201

and 2012/2013 reflected a reversal of only slightly less magnitude. However, such swings are not uncommon over the entire time series.

Using a 5-year running mean boxcar filter to smooth the raw PTI reveals multidecadal-scale oscillations in the north/south component of the drift trajectories (Figure 11), red line and squares), with amplitudes over 7^o latitude. Over the past century, the filtered PTI has undergone four complete oscillations with distinct crossings of the mean, although the durations of the oscillations are not identical: 26 years (1904-1930), 17 years (1930-1947), 17 years (1947-1964), and 41 years (1964-2005). The filtered index indicates that a shift occurred in the mid 2000s to predominantly southerly anomalous flow following a 20+ year period of predominantly northerly anomalous flow. This indicates a return to conditions (at least in terms of surface drift) similar to those prior to the 1977 environmental regime shift.

Factors influencing observed trends: Filtered PTI values greater than the long-term mean are indicative of increased transport and/or a northerly shift in the Alaska Current, which transports warm water northward along the west coast of Canada and southeast Alaska from the south and consequently plays a major role in the Gulf of Alaska's heat budget. Individual trajectories also reflect interannual variability in regional (northeast Pacific) wind patterns.

Implications: The year-to-year variability in near-surface water movements in the North Pacific Ocean has been shown to have important effects on the survival of walleye pollock (*Theragra chalcogramma*) by affecting its spatial overlap with predators (Wespestad et al., 2000), as well as to influence recruitment success of winter spawning flatfish in the eastern Bering Sea (EBS;

Wilderbuer et al. (2002)). Interdecadal changes in the PTI reflect changes in ocean climate that appear to have widespread impacts on biological variability at multiple trophic levels (King, 2005). There is strong evidence that the productivity and possibly the carrying capacity of the Alaska Gyre and of the continental shelf were enhanced during the recent "warm" regime that began in 1977. Zooplankton production was positively affected after the 1977 regime shift (Brodeur and Ware, 1992). Recruitment and survival of salmon and demersal fish species also improved after 1977. Recruitment of rockfish (Pacific ocean perch) and flatfish (arrowtooth flounder, halibut, and flathead sole) increased. However, shrimp and forage fish such as capelin were negatively affected by the 1977 shift (Anderson, 2003). The reduced availability of forage fish may have been related to the decline in marine mammal and seabird populations observed after the 1977 shift (Piatt and Anderson, 1996).

Although the PTI was substantially larger than the mean for 2011-12, it was smaller than the mean in both 2010/2011 and 2012/2013 and its current (5-year averaged) trend remains consistent with a return to conditions associated with the preceding "cold" regime. It may thus be a harbinger of a decadal-scale reduction in regional productivity. In addition, **the trajectory for 2012-13 indicates the potential for southeast Alaska to have experienced an influx of open ocean type organisms at the lower trophic levels**, as well as a southward shift in the "boundary" between sub-arctic and sub-tropical species.

Gulf of Alaska Survey Bottom Temperature Analysis

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Last updated: October 2011

Gulf of Alaska surveys are conducted in alternate even years. For most recent data, see the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Habitat

Structural Epifauna - Bering Sea

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Structural Epifauna - Aleutian Islands

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Nutrients and Productivity

Phytoplankton Biomass and Size Structure During Late Summer to Early Fall in the Eastern Bering Sea

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Last updated: August 2012

Gulf of Alaska surveys are conducted in alternate even years. For most recent data, see the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Trends in Surface Carbon Uptake by Phytoplankton During Late Summer to Early Fall in the Eastern Bering Sea

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Gulf of Alaska Chlorophyll a Concentration off the Alexander Archipelago

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Zooplankton

Bering Sea Zooplankton

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Late Summer/Fall Abundances of Large Zooplankton in the Eastern Bering Sea

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Jellyfish - Eastern Bering Sea

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See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Trends in Jellyfish Bycatch from the Bering Aleutian Salmon International Survey (BASIS)

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Last updated: July 2013

Description of index: Jellyfish sampling was incorporated aboard the BASIS (Bering Aleutian Salmon International Surveys) vessels beginning in 2004 and will continue through 2013. All jellyfish medusae caught in the surface trawl (top 18-20 m of the water column) are sorted by species and subsampled for bell diameter and wet weight. Six species are commonly caught with the surface trawl: *Aequorea* sp., *Chrysaora melanaster*, *Cyanea capillata*, *Aurelia labiata*, *Phacellocephora camtschatica*, and *Staurophora mertensi*. Biomass is calculated for each species and compared across species, and oceanographic domains on the Bering Sea shelf (Inner Domain $<$50m, Middle Domain 50m-100m, Outer Domain $\geq$100m) Yearly distributions throughout the sample grid for all species have been patchy. Despite uneven distributions throughout oceanographic domains, highest concentrations of all species were found to occur in the Middle Shelf Domain. Of the six species sampled, *Chrysaora melanaster* had the highest weight per unit effort (kg) for all years.

Status and trends: In 2012 total jellyfish biomass more than doubled compared to 2011 and was the highest recorded biomass year for our survey (Figure 12). One station in the southern Bering Sea portion of our grid during 2012 was responsible for half the total catch of the entire survey. During 2010, another high biomass year, combined jellyfish species was double the previous high of 2004. Unlike in 2012, half the total catch did not come from a single station but was spread out over the entire sampling grid. Starting in 2007, notable declines in jellyfish species compostion were observed for all taxa except *C. melanaster* and continued through 2012 (Figure 13). The dominant species continues to be *C. melanaster*, nearly quadrupling its biomass in 2012 compared to 2004. During 2007-2012, biomass of all other species have remained low in comparison to 2004-2006, suggesting the trend for the region has shifted from multiple species to a single species dominant.

Factors causing observed trends: The cause for these shifts in biomass and distribution do not seem to rely solely on physical ocean factors (temperature and salinity). These shifts could also be a result of environmental forcing earlier in the growing season or during an earlier life history stage (polyp), which may influence large medusae biomasses and abundances (Purcell et al., 2009).

Implications: Significant increases in jellyfish biomass may redirect energy pathways in the eastern Bering Sea foodweb through jellyfish predation on zooplankton and larval fish, and could result in limiting carbon transfer to higher trophic levels (Condon et al., 2011).

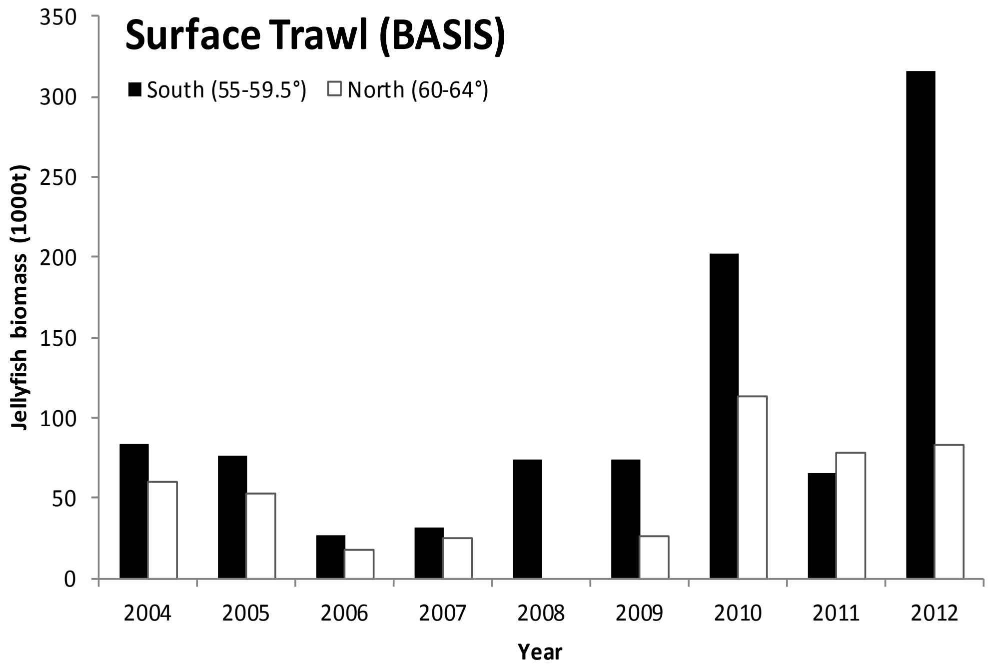

Figure 12: Total jellyfish biomass (1000 t) by year. Includes combined species caught in surface trawls in the Eastern Bering Sea during August-October. Biomass was calculated using average effort per survey area in km^2 by year.

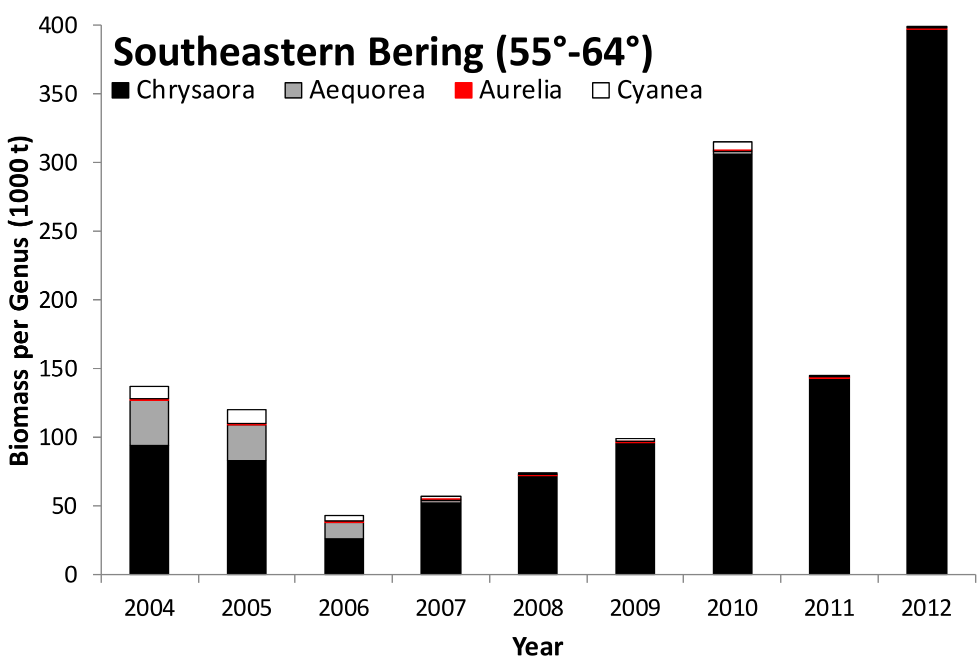

Figure 13: BASIS surface trawl Biomass (1000t) by genus for 2004-2011 in the Eastern Bering Sea during August -October. Biomass was calculated using average effort per survey area in km^2 by year.

Long-term Zooplankton and Temperature Trends in Icy Strait, Southeast Alaska

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Description of index: The Southeast Coastal Monitoring (SECM) project of Auke Bay Laboratories, AFSC, has collected zooplankton and temperature data during fisheries oceanography surveys annually since 1997 (Orsi et al. 2012; `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm`). The SECM project primarily samples 8 stations in the vicinity of Icy Strait in the northern region of southeastern Alaska (SEAK), including monthly sampling with CTDs and plankton nets in May-August. Surface trawling for juvenile Pacific salmon (*Oncorhynchus* spp.), the most abundant forage species in local epipelagic waters in day time, and associated nekton is conducted in June-August. The primary goals of this research are to investigate how climate change may affect SEAK ecosystems, to increase understanding of the early marine ecology of salmon and their trophic linkages, and to develop an annual forecast of the adult pink salmon (*O. gorbuscha*) from stock assessments of juveniles in the prior year (Sturdevant et al., 2012; Fergusson et al., 2013; Orsi et al., 2013). Biophysical parameters representing temperature, zooplankton prey, and fish abundance and condition are used to characterize seasonal and interannual ecosystem conditions for inside waters of northern Southeast Alaska.

This report presents longterm trends for monthly temperature and zooplankton in Icy Strait. The Icy Strait Temperature Index (ISTI, °C) is computed from CTD data at 1-m increments over the 20-m upper water column (≥160 observations per month each year). The ISTI is linked to a climate metric, the El Niño/La Niña-Southern Oscillation (ENSO) Multivariate ENSO Index (MEI) (Wolter, 2012; Sturdevant et al., 2012). We used the mean winter MEI (November to March) for the year prior to the sample year, to capture the lag effect of propagating ocean-atmospheric teleconnections from the equatorial Pacific Ocean (Orsi et al., 2013). Zooplankton total density (number per m^3) and percent composition were computed from 333-μm bongo net samples collected at 4 stations (≤200 m depth) (Orsi et al., 2004; Park et al., 2004). Temperature and zooplankton anomalies were computed as deviations from the longterm monthly mean values. These indices may help to explain climate-related variation in prey fields for diverse fish communities (Sturdevant et al., 2012; Fergusson et al., 2013).

Status and trends: Monthly mean temperatures ranged from approximately 7 °C to 10 °C and anomalies did not exceed ±1.4 °C (Figure 14, top). The ISTI was significantly correlated with the MEI (Figure 14, bottom), with 9 years warmer and 7 years colder than average (9.3 °C). Warm and cold years typically had positive and negative MEI values, respectively. In the most anomalous years, all 4 months were warm (2003 and 2005) or cold (2002, 2006, 2008, 2012; Figure 14, top), whereas moderately warm or cold years had unique months of temperature reversal. For example, the warm years of 2001, 2004, and 2010, were actually colder than average in May, June, and July, respectively.

Long-term mean zooplankton density peaked in May and June at ∼1,700 organisms per m^3, and declined ∼50% by August (Table 1). Density anomalies were mostly negative from 1997-2005, positive in 2006-2009, and negative in 2010-2012 (Figure 15). Total density showed little correspondence with annual temperature trends, with both positive and negative monthly anomalies in both warm and cold years (Figure 15).

Zooplankton was numerically dominated by calanoid copepods, including small species (≤2.5 mm length; ≤74% composition; primarily *Pseudocalanus* spp.) and large species (>2.5 mm; ≤34% com-

Table 2: Zooplankton long-term mean total density (numbers^{-3}) and taxonomic percent composition in Icy Strait, Southeast Alaska, 1997-2012. Data represent 4 stations sampled annually across the strait ($\leq$ 200 m depth) with a 0.6 m diameter 333-μm mesh Bongo net (double-oblique trajectory). Values are references for the 0-lines shown in Figure 15 anomalies.

	Total organisms	% Large calanoids	% Small calanoids	% Euphausiid larvae	% Larvaceans	% Pteropods	% Amphipods	% Decapod larvae	% Other
May	1661	34	48	5	6	<1	<1	<1	6
June	1691	25	57	6	4	2	<1	<1	4
July	1219	15	74	1	3	<1	3	<1	4
August	886	15	71	1	2	4	3	<1	4

position; primarily *Metridia* spp.) (Table 2). Five other taxa important in fish diets (Sturdevant et al. 2012; Fergusson et al. 2013) contributed small percentages. Small and large calanoids typically had inverse monthly composition anomalies that indicated different seasonality and temperature response (Figure 15). However, these anomalies varied from year to year, suggesting different innate timing cues. For example, both 2005 and 2010 were warm years, but positive temperature anomalies were sustained in 2005 (when both large and small calanoid trends reversed abruptly in July), compared to 2010 (when synchronous negative anomalies were sustained). In some years, high percentages of euphausiid larvae (2000, 2002, 2010), larvaceans (2010), or pteropods (2012) contributed to monthly composition anomalies (Figure 15). Such shifts could lead to mismatched timing of prey fields for planktivorous fish.

Factors influencing observed trends: Our research in SEAK over the past 16 years described annual trends in temperature, prey fields, and other biophysical factors (Orsi et al., 2013). We documented a significant link between ISTI and a basin-scale climate index, with limited diet-climate relationships (Sturdevant et al., 2012, 2013; Fergusson et al., 2013). Although subarctic zooplankton typically follow seasonal cycles of abundance, responses to climate change may be species-specific based on life history, seasonal timing cues, physiology, and environmental parameters other than temperature (Mackas et al., 2012), and these responses could depend on the monthly timing, magnitude, and duration of temperature anomalies in warm or cold years. Therefore, the simple ISTI may not explain shifts in abundance and composition of these prey fields, particularly at broad taxonomic scales.

Implications: Climate change can have broad impacts on key trophic linkages in marine ecosystems by changing relationships of the biophysical environment with seasonal abundance, composition, timing, and utilization of prey (Mackas et al., 2004, 2012; Coyle et al., 2011). Although links between climate and plankton have been documented in Alaskan waters, mechanisms are poorly understood. In the Bering Sea, the magnitude and timing of production of the large copepod, Calanus marshallae, varied among years, reflecting interannual ocean-atmosphere conditions (Baier and Napp, 2003), and in SEAK, large copepods with long life spans were thought to be more sensitive to climate fluctuation than small copepods (Park et al., 2004). Temperature and other climate metrics may affect fish production and recruitment directly or indirectly, through prey resources (Beamish et al., 2004, 2012; Coyle et al., 2011). In dynamic ecosystems such as SEAK (Weingartner et al., 2009), the effects of climate variation on prey fields are likely to be complex, varied, and difficult to distinguish from natural variation, particularly if annual temperature changes are moderate. However, further analysis of the potentially more direct links between

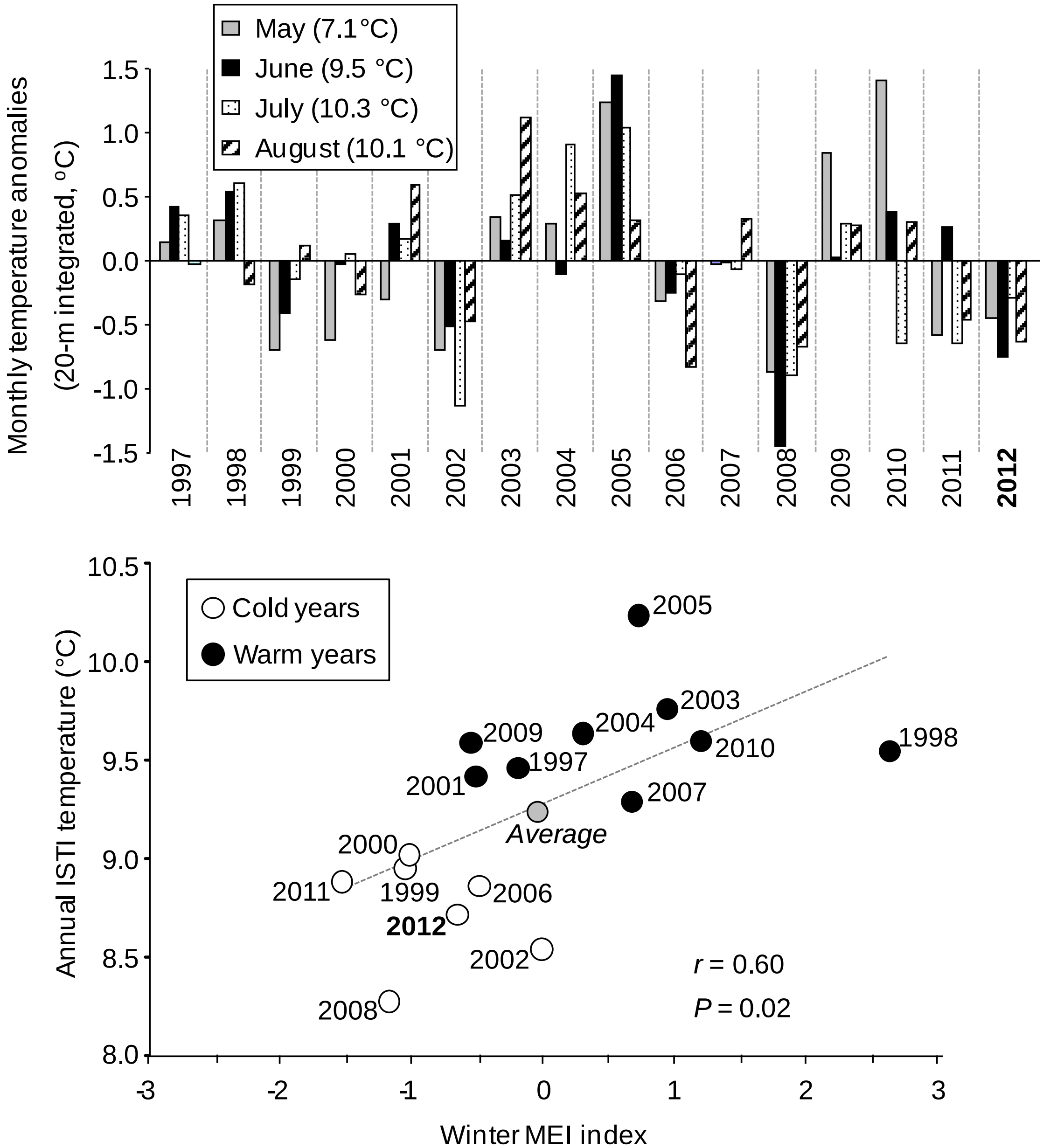

Figure 14: Marine climate relationships for the northern region of Southeast Alaska from the SECM 16-year time series, 1997-2012. Upper panel: mean monthly temperatures (°C, 20-m integrated water column) in Icy Strait; lower panel: correlation of mean annual temperature (°C, 20-m integrated water column) with the Multivariate ENSO Index (MEI), showing warm-versus-cold years. Long-term mean temperatures are indicated in the key.

monthly temperature and zooplankton secondary production may lead to improved understanding of marine mechanisms that influence fish recruitment during periods of climate change (Downton and Miller, 1998; Francis et al., 1998).

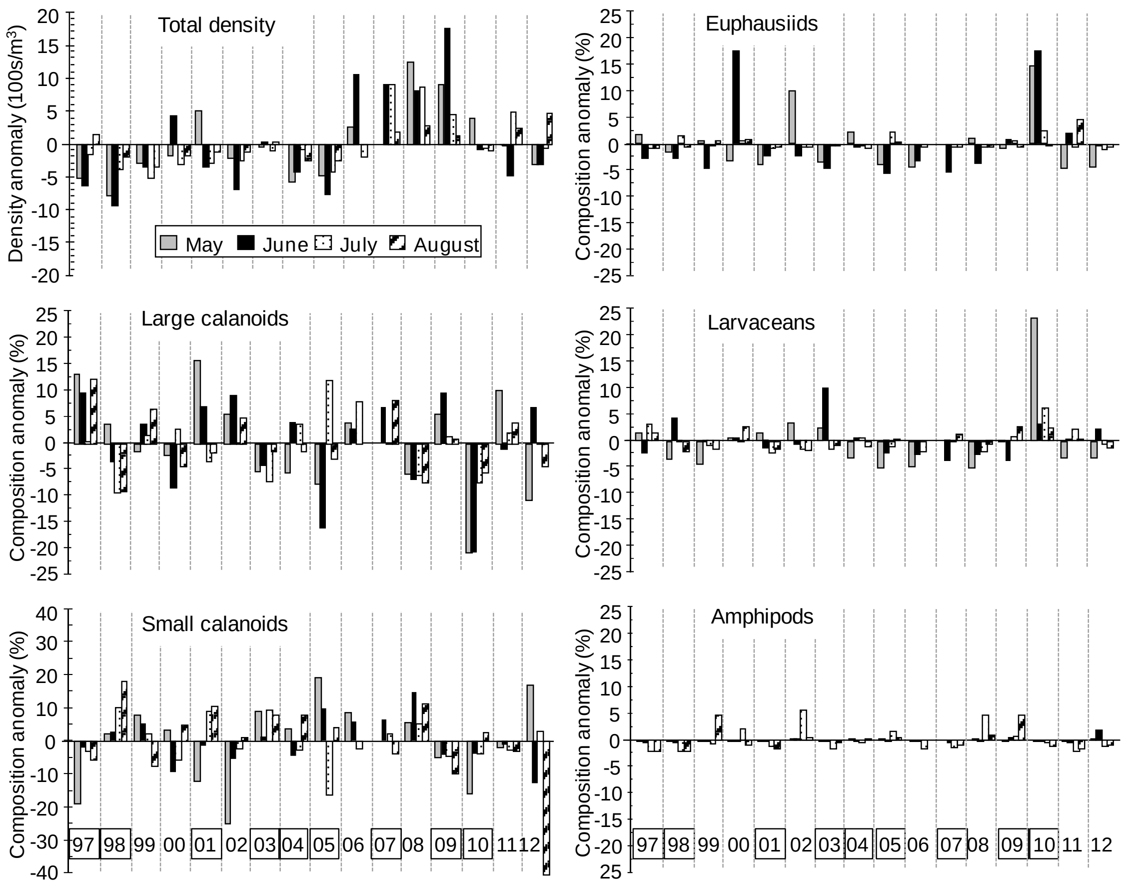

Figure 15: Zooplankton density and composition anomalies for the SECM 16-yr time series from Icy Strait, Southeast Alaska, 1997-20121. Long-term monthly means are indicated by the 0-line (values given in Table 2). Data (shaded bars) are deviations for total density (number/m^3; top left panel), and percent numerical composition of taxa important in fish diets. No samples were available for August 2006 or May 2007. Warm years are indicated in boxes on the x-axis; see Figure 14.

Continuous Plankton Recorder Data from the Northeast Pacific

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Last updated: July 2013

Description of index: Continuous Plankton Recorders (CPR) have been deployed in the North Pacific routinely since 2000. Two transects are sampled seasonally, both originating in the Strait of Juan de Fuca, one sampled monthly (∼ Apr-Sept) which terminates in Cook Inlet, the second sampled 3 times per year which follows a great circle route across the Pacific terminating in Japan. Several indicators are now routinely derived from the CPR data and updated annually. In previous reports we have focussed only on zooplankton indices, however, larger hard shelled phytoplankton are also sampled by the CPR. Whilst undoubtedly under-sampling much of the phytoplankton community, the CPR is considered to be an internally consistent sampler and a time series of phytoplankton indices should, therefore, be informative. In this report we include large diatom anomalies for three regions (Figure 16). We also update zooplankton indicators for these same regions: mesozooplankton biomass and mean copepod community size (Richardson et al., 2006) as an indicator of community composition. Anomaly time series of each index have been calculated as follows: A monthly mean value (geometric mean) for all sampled years was first calculated. Each sampled month was then compared to the mean of that month and an anomaly calculated (Log10). The mean anomaly of all sampled months in each year was calculated to give an annual anomaly (Figure 17).

The indices are calculated for three regions; the oceanic North-East Pacific, the Alaskan shelf SE of Cook Inlet and the deep waters of the southern Bering Sea (Fig 1). The NE Pacific region has the best sampling resolution as both transects intersect here. This region has been sampled up to 9 times per year with some months sampled twice. The southern Bering Sea is sampled only 3 times per year by the east-west transect while the Alaskan shelf region is sampled 5-6 times per year by the north-south transect.

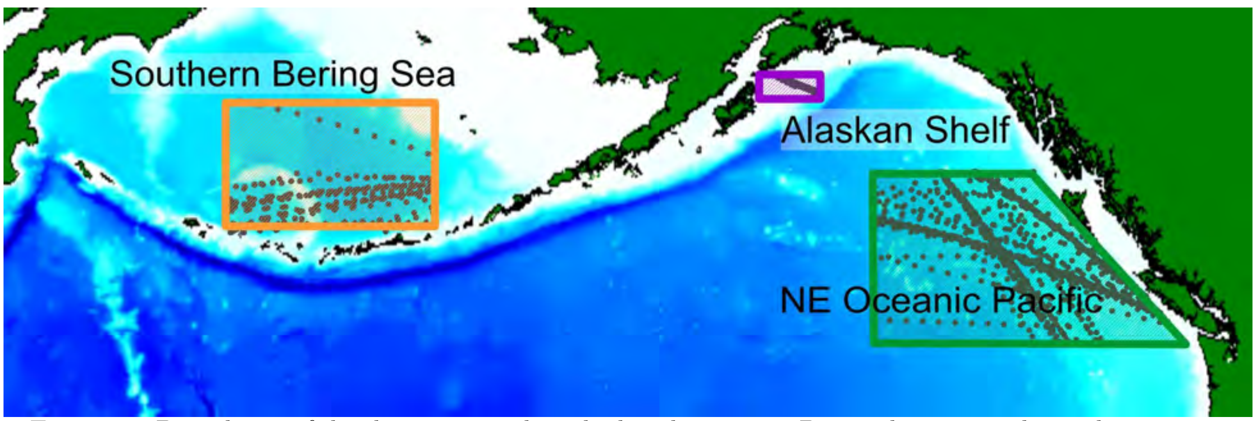

Figure 16: Boundaries of the three regions described in this report. Dots indicate actual sample positions (note that for the Alaskan Shelf region the multiple transects overlay each other almost entirely).

Status and trends: Lower trophic level productivity apparently increased in 2012 in the NE Pacific and Alaskan Shelf, in contrast to 2011 which saw the lowest levels of diatom and mesozooplankton biomass in many of the regions (not shown) sampled by the CPR. In fact, in the NE Pacific, mesozooplankton biomass had the most positive anomaly of the time series in 2012. Values for the southern Bering Sea were low in 2012, however. Copepod community size showed positive anomalies in all 3 regions, indicative of cool conditions where subarctic species predominate; all three regions had below average sea surface temperatures through spring and summer 2012.

Factors influencing observed trends: Changes in ocean climate can affect each of these indicators. There is a strong correlation between large diatom abundance and mesozooplankton abundance on the Alaskan shelf (where large diatoms are a larger component of the phytoplankton), less of a relationship in the NE Pacific and no relationship in the southern Bering Sea, where the diatoms retained by the CPR are likely a much smaller component of the phytoplankton community. Cool conditions are generally favourable for the larger subarctic copepod species which have high individual biomass.

Implications: Each of these variables is important to the way that ocean climate variability is passed though the phytoplankton to zooplankton and up to higher trophic levels. Changes in community composition (e.g. abundance of large diatoms, prey size as indexed by mean copepod community size) may reflect changes in the nutritional quality of the organism to their predators. Changes in abundance or biomass, together with size, influence availability of prey to predators.

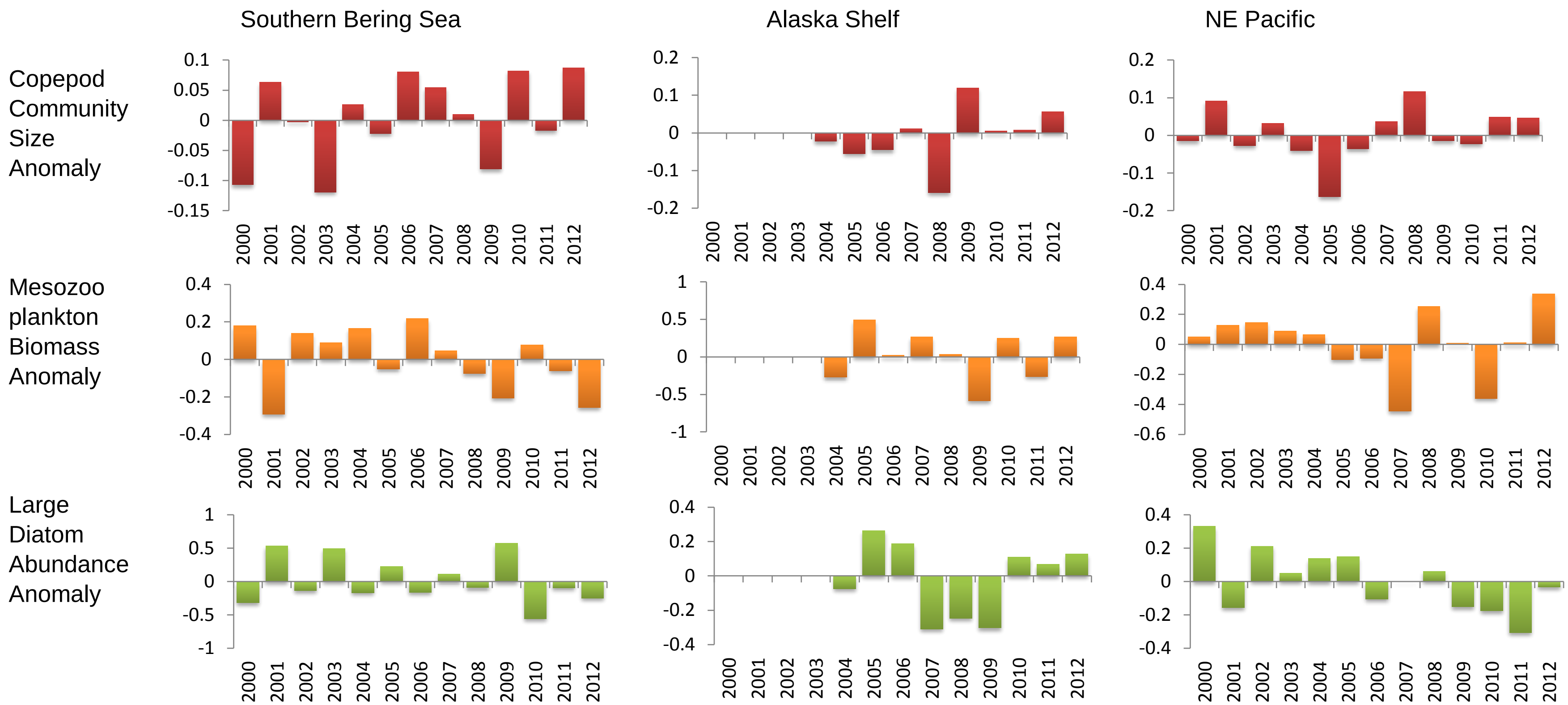

Figure 17: Annual anomalies of three indices of lower trophic levels (see text for description and derivation) for each region shown in Figure 1. Note that sampling of this Alaskan Shelf region did not begin until 2004.

Forage Fish

Fall Condition of YOY Predicts Recruitment of Age-1 Walleye Pollock

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Last updated: August 2013

Description of index: Average Energy Content (AEC) is the product of the average individual mass and average energy density (i.e. kJ/fish) of YOY pollock collected from BASIS surveys. Average individual mass is estimated at sea from the mean individual mass of YOY pollock in each haul weighted by catch of YOY pollock. The average energy density of YOY pollock is estimated in the laboratory using fish collected at random from each haul and is also weighted by catch. The product of the two averages represents the total energy content of the average YOY pollock for a given year.

The analytical procedures for measuring energy density follow strict protocols. Fish are retained from each haul during the BASIS survey, frozen and shipped to Auke Bay for analysis. Catch records are examined to identify the number of fish to process from each haul so that at least 50 fish are processed. Fish are dried, homogenized and combusted in our bomb calorimeter. Along with each batch of 15 samples we combust two samples of benzoic acid and a reference material to verify the accuracy of our methods. In addition, one of the samples is duplicated to verify that the precision of our estimates is within 3%.

Previously we have related AEC to the number of age-1 recruits per spawner using the index of adult female spawning biomass as an index to the number of spawners. This year we are able to introduce a comparison between AEC and the biomass of age-3 recruits per spawner because we have enough observations of energy density. We anticipate that estimates of the number of age-3 pollock in the eastern Bering Sea is a more stable estimate of recruitment in the stock assessment.

Status and trends: Energy density (kJ/g) and mass (g) of YOY pollock have been measured annually since 2003. Over that period energy density has varied with the thermal regime in the Bering Sea. Between 2003 and 2005 the southeastern Bering Sea experienced warm conditions characterized by an early ice retreat. Ice retreated much later in the years following 2006 and 2006 was intermediate. The transition between the warm and cool periods is clearly observed in plot relating energy density to collection year (Figure 18). Plotting energy density for each year reveals this transition; energy density increases from values near 3.6 kJ/g in 2003-2005 to values near 5.0 kJ/g in 2008-2012. In contrast, the size of the fish has been less influenced by thermal regime. In the warm years mass averaged 2.0 g compared with 2.3 g in the cold years.

Contrasting the AEC of YOY pollock with year class strength in the age-structured stock assessment suggests the condition of pollock prior to their first winter predicts their survival. The AEC of YOY pollock between 2003 and 2012 accounted for 83% of the variation in the number of age-1 recruits per spawner (Figure 19). Similarly, the AEC of YOY pollock accounted for 73% of the variation in the biomass of age-3 recruits starting in 2006. In 2012 the AEC of YOY pollock was low (6.52 kJ/fish) suggesting the number of age-1 recruits per spawner should below the overall median level in 2013 and the biomass of age-3 recruits should be less than median in 2015.

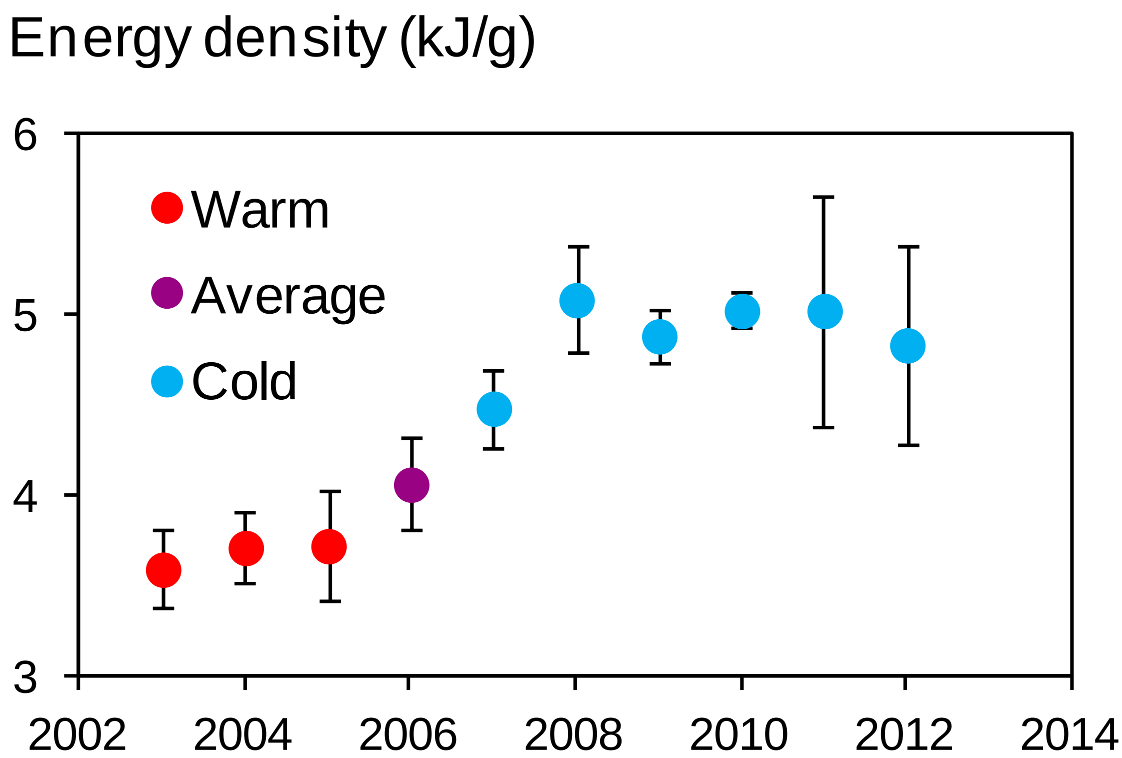

Figure 18: Annual changes in the average energy density of age-0 pollock sampled by surface trawl during BASIS surveys

Factors influencing observed trends: Pollock are susceptible to size dependent mortality during their first winter (Heintz et al., 2010). This effect can be particularly important in determining recruitment. For example, size dependent mortality during winter among salmon can be proportionally as high as mortality during the first 40 days at sea (Farley et al., 2007). Thus the critical size hypothesis posits a positive effect of size on winter survival. While size may be a good predictor within a year, BASIS data indicate a weak relationship between size and recruitment among years. Similarly, high energy density does not necessarily predict high survival among years because energy density is mass normalized and does not convey information about size. AEC of individual YOY pollock integrates information about size and energy density into a single index.

YOY pollock have a relatively narrow window within which they can provision themselves prior to winter. Larval pollock allocate the majority of their ingested energy into developmental processes leaving little energy for somatic growth or sequestration of energy stores. They can only invest energy in growth and storage after they have successfully transitioned into fully developed juveniles (Siddon et al., 2013). Their success at exploiting this window likely depends on water temperatures, prey quality and foraging costs. Cold years appear to be associated with greater densities of euphausiids, medium and large copepods in the middle domain (Hunt et al., 2011). These species are higher in lipid affording pollock a higher energy diet than that consumed in warm years. In addition the lower temperatures optimize their ability to store lipid (Kooka et al., 2007). While cold conditions in the Bering Sea are associated with improved nutritional status of YOY pollock prior to winter, **2012 demonstrates conditions can be too cold to support good survival**.

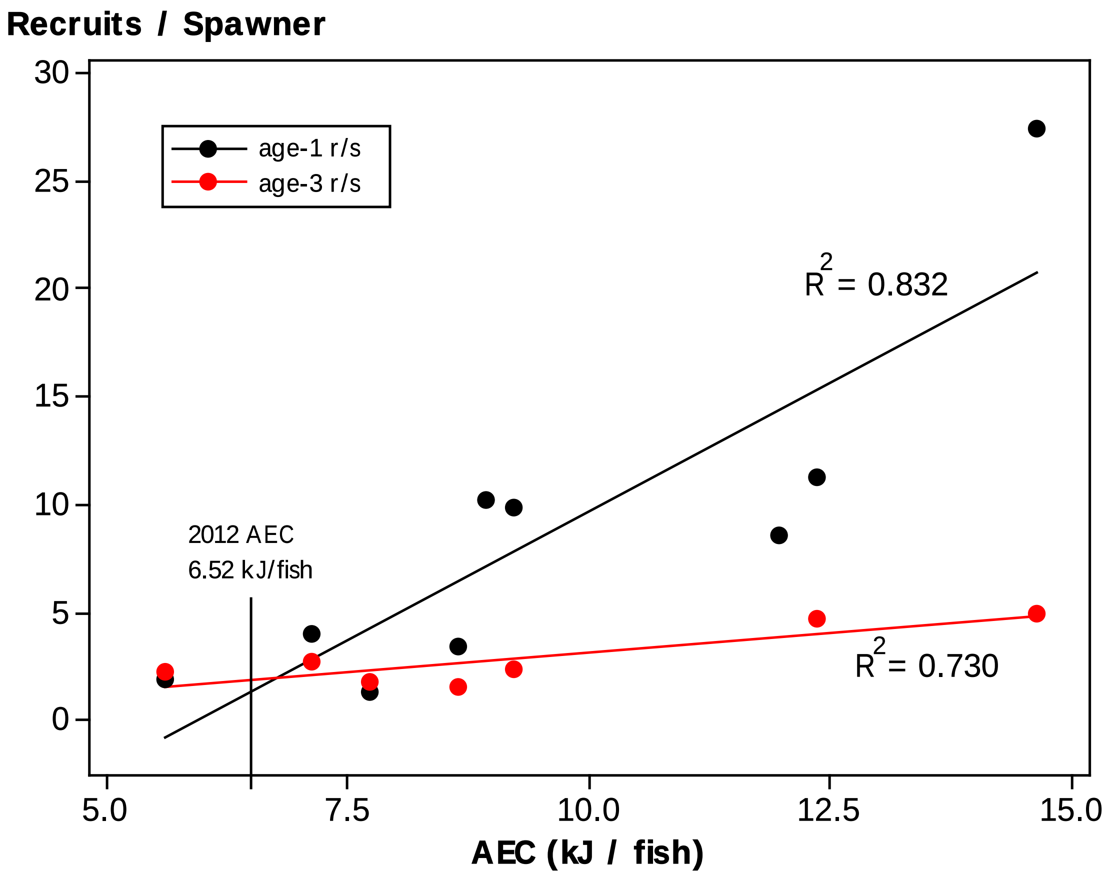

Figure 19: Relationship between average energy content (AEC) of individual age-0 pollock and the number of recruits per spawner as shown in the 2012 stock assessment (Ianelli et al., 2012). Recruits are measured as the number of age-1 pollock or the biomass of age-3 recruits.

In May of 2012 ice cover still reached as far south as the Alaska peninsula suggesting summer temperatures were very low when larvae were developing. Consequently, YOY pollock sampled on the BASIS survey were the smallest in the 10 year time series.

Implications: The current data indicate that recruitment to age-1 for the 2012 year class should be relatively weak. A return to warmer conditions than experienced in 2012 should improve recruitment of the 2013 year class.

Forage Fish CPUE - Bering Aleutian Salmon International Survey - BASIS

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Last updated: October 2012

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Gulf of Alaska Small Mesh Trawl Survey Trends

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See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Regional Distribution of Juvenile Salmon and Age-0 Marine Fish in the Gulf of Alaska

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Last updated: August 2012

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Herring

Togiak Herring Population Trends

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See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Prince William Sound Pacific Herring

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Last updated: October 2008

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Southeastern Alaska Herring

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Last updated: October 2012

Description of index: Pacific herring (*Clupea pallasi*) populations in southeastern Alaska are monitored by the Alaska Department of Fish and Game. Populations are tracked using spawn indices. Stock assessments that combine spawn indices with age and size information have been conducted each fall by the Alaska Department of Fish and Game for nine spawning areas in southeastern Alaska for most years since 1980. The magnitude and regularity of spawning in these areas has warranted annual stock assessment surveys and potential commercial harvests at these locations during most of the last 30 years. Although spawning occurs at other locales throughout southeastern Alaska, little or no stock assessment activity occurs at these locations other than occassional aerial surveys to document the miles of spawn along shoreline. Spawning at the nine primary sites for which regular assessments are conducted probably accounts for the majority of the spawning biomass in southeastern Alaska in any given year.

Status and trends: Herring spawning biomass estimates in southeastern Alaska often change markedly from year to year, rarely exhibiting consistent, monotonic trends (Figures 20, 21). Over the period 1980 through 2012, several stocks have undergone at least moderate increasing trends, with four of the nine primary, surveyed locations (Sitka Sound, Hoonah Sound, Seymour Canal, and Craig) exhibiting a pronounced trend of increasing biomass, and one area (Kah Shakes/Cat Island) exhibiting a pronounced downward trend. Although the estimated total mature herring biomass in southeastern Alaska has been above the long-term (1980-2012) median of 89,709 tons since 1998, and continues to be in 2012, an apparent decrease in biomass has been observed between 2011 and 2012 (Figure 22). Notable drops in biomass were observed for some spawning areas in particular, including Hoonah Sound and Sitka Sound. Although the observed drop in biomass appears to be substantial, it is too early to conclude from a single year whether this represents the beginning of period of decline, or natural volatility of the population. The herring biomass in Sitka Sound continues to be by far the highest in the region. Since 1980, herring biomass near Sitka has contributed between 37% and 72% (median of 55%) of the total estimated annual mature biomass among the nine surveyed spawning locations. Excluding the Sitka biomass from the combined estimate, southeastern Alaska herring biomass has been at or above the 25-year median of 41,010 tons in every year since 1998, except for 2000 (Figure 22).

In southeastern Alaska, the first potential age of recruitment to the mature population of herring is three years old. Estimated abundance of total age-3 herring (used to gauge recruitment) has varied greatly among and within stocks over time (Figures 20, 21). The number of age-3 herring has been estimated for Seymour Canal, and Sitka for most years since 1980; for Craig in every year since 1988; and for West Behm Canal, Ernest Sound, Hobart Bay-Port Houghton, and Hoonah Sound for most years since 1995. Estimates of age-3 herring abundance for Tenakee Inlet are not available at this time. An oscillating recruitment pattern with strong recruit classes every three to five years was observed for Sitka Sound and Craig stocks prior to 1997. For Sitka Sound, the stock with the greatest annual recruit abundance, oscillating years of extremely high and low recruit abundance in the 1980s and early 1990s changed to more consistent, intermediate recruit abundances in the

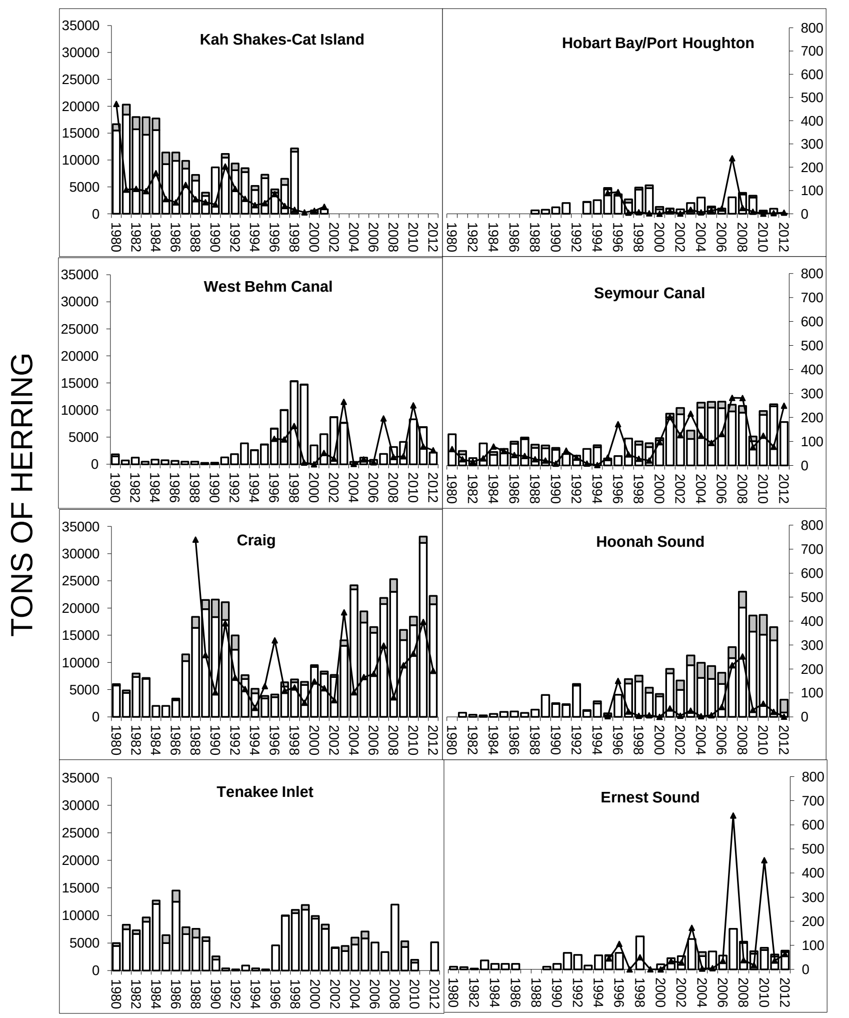

Figure 20: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at eight major spawning locations in southeastern Alaska, 1980-2012. Estimates of age-3 abundance for Tenakee Inlet were unavailable by time of publication.

mid-1990s through 2011 (Figure 21).

Factors influencing observed trends: The generally increasing long-term trends of biomass observed for many herring stocks in southeastern Alaska, particularly over the past decade, are thought to be at least partially a result of higher survival rates among adult age classes. Age-structure analysis modeling of several herring stocks in the region suggests that changes in survival during the late 1990s are partially responsible for the observed increasing and high herring abundance levels. For example, for the Sitka stock, for the period 1980-1998, survival has been estimated to be 58%, while for the period 1999-2012 survival is estimated at 77%. Similar shifts in survival have been estimated for the Craig and Seymour Canal stocks. These shifts in survival coincide with time periods of change in ocean conditions, as indexed by the Pacific Decadal Oscillation (PDO).

There has been some speculation and debate about the extent to which commercial harvests may have contributed to marked declines in estimated abundance and/or localized changes in herring spawning sites in a few areas in southeastern Alaska, notably Revillagigedo Channel (Kah

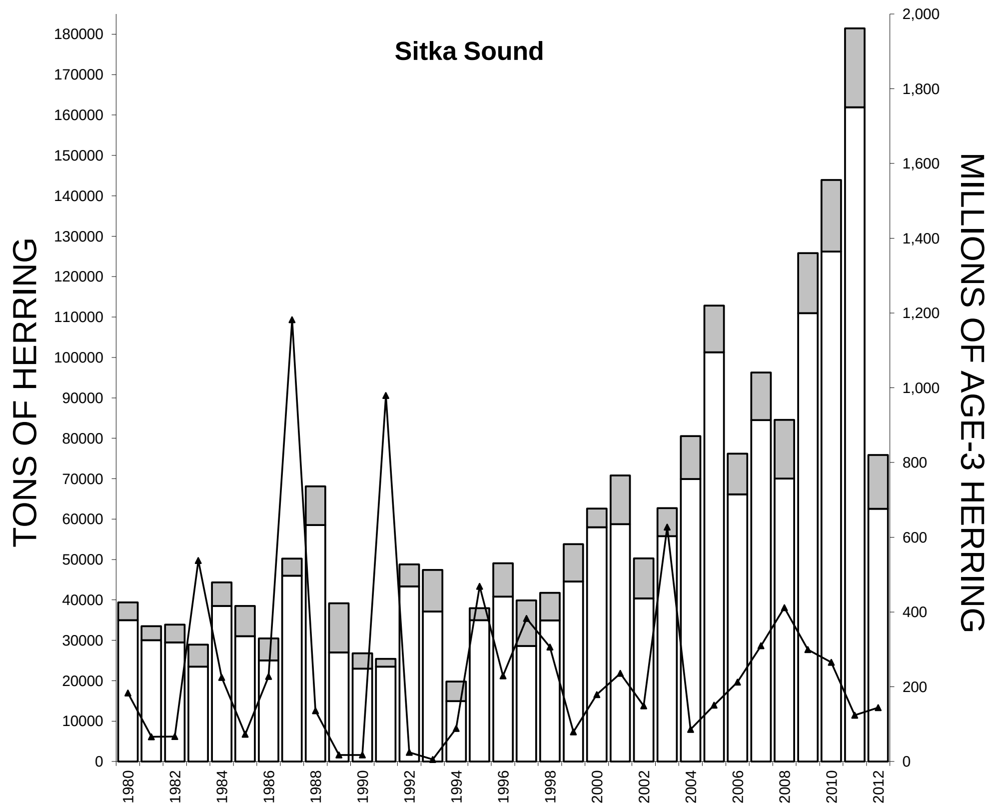

Figure 21: Estimated post-fishery mature herring biomass (white bars in tons), catch (gray bars in tons) and age-3 abundance (black line) at Sitka Sound spawning location in southeastern Alaska, 1980-2012.

Shakes/Cat Island) and Lynn Canal. In the Revillagigedo Channel area, significant spawning and a fishery occur at Annette Island, a site outside the management jurisdiction of the State and from which limited data are gathered by the department. Although spawning activity at the Kah Shakes and Cat Island sites in Revillagigedo Channel has declined in recent years, this decline may be at least partially attributable to a shift of herring to spawning grounds within the Annette Island Reserve, bordering Revillagigedo Channel. In the Lynn Canal spawning area surveys of spawning biomass have not been conducted regularly. Reasons for the biomass decline in the area are unknown but possibilities include commercial harvest, increased predation by marine mammals and fish, and shoreline development on or near spawning grounds.

Implications: The harvest rate policy in southeastern Alaska allows for harvest rates ranging from 10 to 20% of the forecasted spawning biomass when the forecast is above a minimum threshold biomass. The rate of harvest depends upon the ratio of forecast to threshold (the more the forecast exceeds the threshold, the higher the harvest rate). Consequently, catch limits have varied in direct proportion to forecast biomass (Figures 1a,1b). The lower abundance of mature herring observed at some spawning areas will likely reduce commercial harvest opportunity in the region due to lower guideline harvest levels. However, the short life-span of herring and the natural volatility of stock levels, particularly of smaller-sized stocks, make it difficult to speculate on long-term fishery implications.

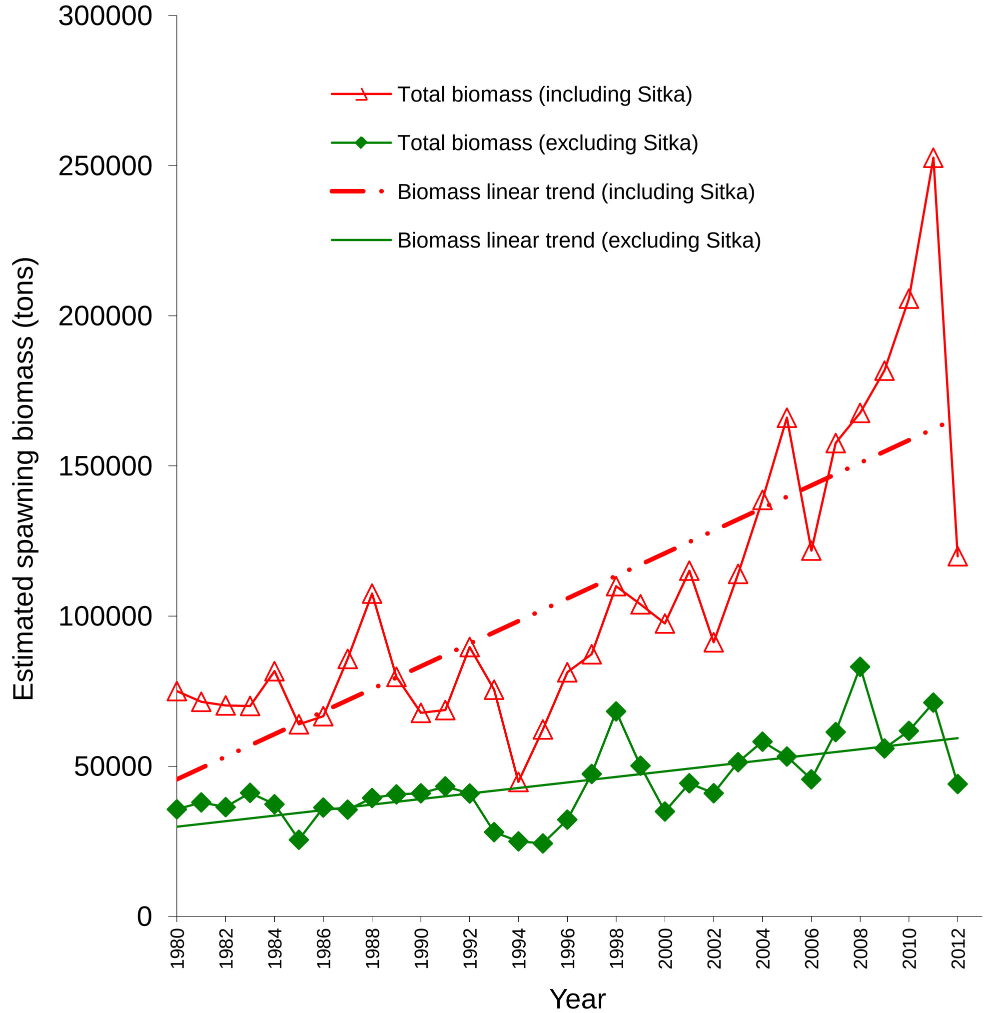

Figure 22: Estimated combined annual mature herring biomass (including and excluding Sitka) at major southeastern Alaska spawning areas, 1980-2012.

Salmon

Editor's synthesis: Alaska salmon returns have been generally strong over the past 35-40 years. Some smaller runs such as Bering Sea chinook and chum have had direct impacts on groundfish fisheries through bycatch limits in years with especially poor runs and/or high bycatch. Forecasts for 2014 salmon returns are currently unavailable, so predicting the impact of salmon bycatch on groundfish fisheries is not possible.

Pink salmon returns in the GOA are predicted to be high in 2013 (2011 brood year), keeping with the pattern of large returns for odd-year classes. However, marine survival of 2011 pink salmon (as evidenced by Prince Willian Sound hatchery returns) was low, despite high predicted returns (in SEAK), potentially indicating some density dependence. Marine survival of the 2010 year class (at sea during the purported low productivity 2011 season in the GOA (see Hot Topics in Zador (2012))) is currently unknown, but there were low returns and harvests in SEAK.

Historical and Current Alaska Salmon Trends

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Description of index: This contribution provides historic and current catch information for salmon of the Bering Sea and Gulf of Alaska and takes a closer look at two stocks that could be informative from an ecosystem perspective, Bristol Bay sockeye salmon and Prince William Sound hatchery pink salmon. This contribution summarizes available information that is included in current Alaska Department of Fish and Game (ADF&G) agency reports (e.g., Eggers et al. (2013)).

Pacific salmon in Alaska are managed in four regions based on freshwater drainage basins, Southeast/Yakutat, Central (encompassing Prince William Sound, Cook Inlet, and Bristol Bay), Arctic-Yukon-Kuskokwim, and Westward (Kodiak, Chignik, and Alaska peninsula (`http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmonareas`). ADF&G prepares harvest projections for all areas rather than conducting run size forecasts for each salmon run. There are five Pacific salmon species with directed fisheries in Alaska; they are sockeye salmon (*Oncorhynchus nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), Chinook salmon (*O. tshawytscha*), and coho salmon (*O. kisutch*).

Status and trends: Catches from directed fisheries on the five salmon species have fluctuated over the last 35-40 years (Figure 23) but in total have been generally strong. According to ADF&G, total salmon commercial harvests from 2012 totaled 127.1 million fish, approximately 5 million less than the preseason forecast of 132.1 million. The 2012 total salmon harvest is about 50 million less than the 2011 total harvest of 177.1 million. ADF&G is forecasting an increase in the total commercial salmon catch to 178.8 million fish in 2013, due to an expected increase in the number of pink salmon. Projections for 2014 will not be available until February 2014.

Bering Sea Chinook salmon abundance in the Arctic-Yukon-Kuskokwim region has been declining since 2007 and no commercial periods targeting Chinook salmon were allowed during the 2012 summer season in the Yukon Area. In the Kuskokwim Area, Chinook salmon abundance was poor and only 2 of 9 escapement goals were met. In Bristol Bay, the 2012 Chinook salmon harvest was below average in every district, and overall was approximately 75% below the average for the last 20 years.

The 2012 catch of coho salmon in Bristol Bay was 26% above the recent 20 year average, with the majority of the catch in the Nushagak District. Coho salmon harvests were also above average in the Arctic-Yukon-Kuskokwim region. Chum salmon catches in Bristol Bay were 44% below the 20 year average, while harvests were above average in the Arctic-Yukon-Kuskokwim region.

Recruitment for most Bristol Bay sockeye salmon stocks was moderate to strong in the 1980s and into the mid-1990s. The number of returning adult sockeye salmon produced from each spawner increased dramatically for most Bristol Bay stocks, beginning with the 1973 brood year (>1979

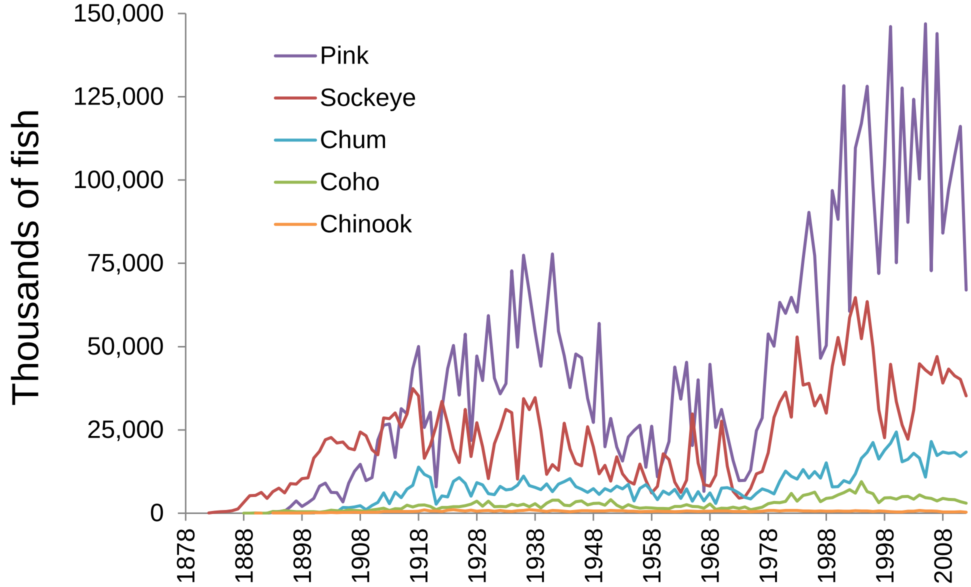

Figure 23: Alaskan historical commercial salmon catches. 2012 values are preliminary. (Source: ADF&G, `http://www.adfg.alaska.gov`. ADF&G not responsible for the reproduction of data.)

return year) (Fair, 2003). Poor returns in 1996-98, however, suggested a return to a level of productivity similar to the pre-1978 period (Fair, 2003). Fish from the 1996-98 return years reared in the ocean when temperatures were above average, whereas cooler than average ocean temperatures characterized the pre-1978 period. Bay-wide forecasts have been fairly accurate in recent years, although forecasts to individual rivers have been less accurate. Historically, total runs to Bristol Bay have been highly variable, but in recent years, 2004-2010, sockeye salmon runs have been well above the long term mean (Figure 24). The 2011 and 2012 runs of 31.9 and 29.1 million fish respectively, were closer to the long-term historical average (1963-2011) of 32.38 million fish. The run size forecasted for 2013 Bristol Bay sockeye is 26.03 million.

Gulf of Alaska In the Southeast/Yakutat region, 2012 salmon harvests totaled 37.0 million, which was well below the 53.7 million average harvest over the most recent ten years but was near the long-term average (since 1962) of 39.3 million fish. Pink salmon comprised 58% of the total number of salmon harvested. Since 2006 pink salmon returns have followed a cycle of strong odd years and weak even years. The total salmon harvested (pounds) in 2012 was less than 2011 but was comparable to 2010.

In the Prince William Sound Area of the Central region, the total salmon harvest was 35.0 million fish, of which 27.2 million were pink salmon. The purse seine commercial common property fishery harvest of 24.0 million pink salmon was the fourteenth highest since 1971, which included about 13% wild pink salmon. Historically, pink salmon catches increased in the late 1970s to the mid-1990s and have generally remained high in all regions in the last decade. Marine survival of Prince William Sound hatchery pink salmon does not appear to have shifted after the 1988/89 or the 1998/99 climate regime shifts (Figure 25). Marine survival of 11.17% in 2010 (2008 brood year) was an all-time high since 1977 but dropped to 4.34% in 2011 (Botz et al. 2013).

In the Southeast/Yakutat region, the harvest of 282,000 Chinook salmon was near the long-term

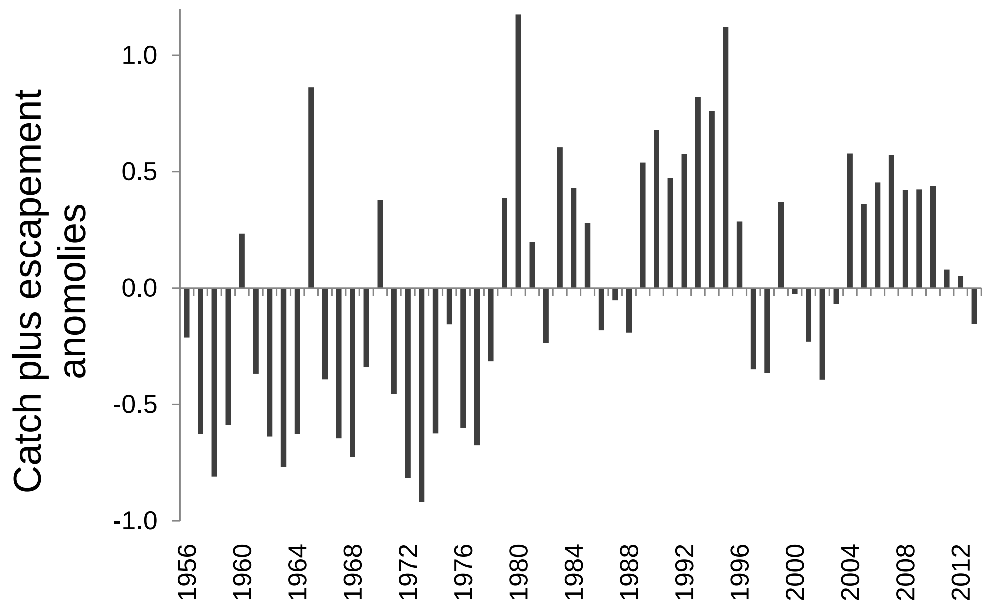

Figure 24: Historical catch plus escapement anomalies of Bristol Bay sockeye salmon, 1956-2013. Data provided by Charles Brazil (ADF&G). Note: the value for 2013 is preliminary and subject to revision.

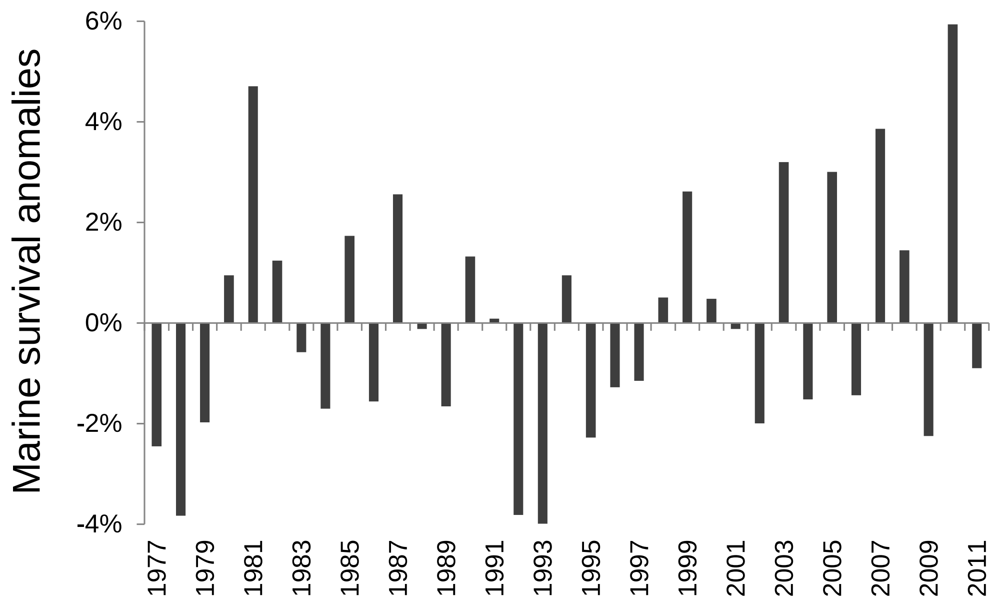

Figure 25: Marine survival of Prince William Sound hatchery pink salmon by year of return (brood year +2 years). Data reproduced from Botz et al.(2013).

average harvest of 300,000 fish, but well below the recent 10-year average harvest of 359,000. Similarly, the harvest of 2.1 million coho salmon was equivalent to the long-term average but below the recent 10-year average of 2.6 million fish. In contrast, the commercial harvest of 12.4 million chum salmon in the Southeast/Yakutat region was above the recent 10-year average harvest (9.8 million) and well above the long-term average harvest (5.4 million).

Factors influencing observed trends: In the Bering Sea, chum salmon are generally caught incidental to other species and catches may not be good indicators of abundance. There were no directed openings for Chinook salmon in the Yukon Area or Nushagak district of Bristol Bay in 2012 due to low early season returns. In other areas of Bristol Bay, Chinook are taken incidentally and mainly in the early portions of the sockeye salmon fisheries.

Bristol Bay sockeye salmon display a variety of life history types. For example, their spawning habitat is highly variable and demonstrates the adaptive and diverse nature of sockeye salmon in this area (Hilborn et al., 2003). Therefore, productivity within these various habitats may be affected differently depending upon climate conditions, for example, so more diverse sets of populations provide greater overall stability (Schindler et al., 2010).

Pink salmon is the most abundant Pacific salmonid species. While both natural and hatchery populations return to Prince William Sound, a large majority of the returning fish are hatchery fish, upwards of up to one half billion are released from four hatcheries (Kline et al., 2008). Pink salmon have an abbreviated life cycle, consisting of three phases 1) brood year, 2) early marine year, and 3) return year (Kline et al., 2008).

Pink salmon run strength is established during early marine residence (Cooney and Willette, 1997). Diet and food availability may be factors that influence growth rates during this early marine residence period. Willette and Cooney (1991) found that productivity of pink salmon in southeast Alaska is sensitive to fry-year spring time temperatures.

Implications: Directed salmon fisheries are economically important for the state of Alaska. Salmon have important influences on Alaska marine ecosystems through interactions with marine food webs as predators on lower trophic levels and as prey for other species such as Steller sea lions. The trend in total salmon catch in recent decades has been for generally strong harvests, despite annual fluctuations. A continued strong presence of salmon will maintain their influence on marine food webs.

Forecasting Pink Salmon Harvest in Southeast Alaska

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Last updated: July 2013

Description of index: An objective of the Alaska Fisheries Science Center (AFSC), Auke Bay Laboratories (ABL) Southeast Alaska Coastal Monitoring (SECM) project `http://www.afsc.noaa.gov/abl/msi/msi_secm.htm` is to understand the effects of climate and ocean on year class strength of salmon and ecologically-related species in Southeast Alaska (SEAK). Since 1997, the SECM project has collected a time series of data using surface trawls and oceanographic instruments in coastal SEAK which has allowed an annual index of ecosystem metrics to be constructed and used for pre-season pink salmon (*Oncorhynchus gorbuscha*) forecast models. Pink salmon are an ecologically and economically important species in SEAK ($92.5 M in 2011) that do not lend themselves to traditional sibling or stock assessment models because of their brief ocean life history. Adult returns are notoriously difficult to forecast because their brief two-year life history includes only one ocean winter and therefore precludes the use of younger returning ocean age classes to predict cohort abundance. Thus, an SECM pink salmon pre-season forecast model was developed beginning in 2004 to: 1) help fishery managers maintain sustainable fisheries, 2) meet the pre-season planning needs of the resource stakeholders in the commercial fishing industry, and 3) gain a better understand of mechanisms related to salmon production in the Gulf of Alaska (GOA) large marine ecosystem.

Status and trends: Since 1960 pink salmon year-class success has varied widely, with harvests ranging from 3 to 78 million fish annually in SEAK. This variability may result from dynamic ocean conditions or ecological interactions that affect juvenile salmon. Additionally, pink salmon production in SEAK is predominately derived from mostly (>95%) wild stocks of varied run timings that originate from >2,000 anadromous streams throughout the region. Therefore, the SECM approach has been to sample 4-65 km offshore in the vicinity of Icy Strait on monthly research surveys. This sampling locality integrates an amalgam of SEAK stocks since it is the principal northward migration corridor in SEAK. Oceanographic sampling is conducted in May, June, July, and August, while surface trawling for epipelagic fish species is conducted in the latter three months as juvenile salmon are actively migrating. The SECM data has also been used to describe epipelagic fish assemblages in the Alaska Coastal Current compared to the California Current (**?**), to define Essential Fish Habitat for Pacific salmon in the U.S. Exclusive Economic Zone of Alaska (**?**), and to document life history patterns of threatened and endangered salmon stocks off SEAK (**?**). For the pink salmon forecasting, SECM data is used with other regional and basin-scale data sources to construct an ecosystem matrix of input and response variables.

Researchers from the SECM project have provided forecasting information to stakeholders of the pink salmon resource of SEAK since 2004 (Wertheimer et al. 2006). These forecasts have allowed stakeholders to anticipate the harvest with more certainty than previous forecasting methods. For example, in eight of the past nine years, SECM forecast estimates have only deviated from the actual harvests by an average of 7% (`http://www.afsc.noaa.gov/abl/msi/msi_sae_psf.htm`) (Figure 26). Data from juvenile pink salmon catches (CPUE) are also shared with the Alaska Department of Fish and Game (ADFG) to help refine their SEAK pink salmon harvest forecast that is developed by a different method.

Factors influencing observed trends: Selected ecosystem metrics associated with SEAK adult pink harvest over the 16-year SECM time series are shown in Figure 27 below. Note that in addition to CPUE, four other variables are significantly correlated with harvest (Peak migration month, NPI, %pink in June-July trawl hauls, and the ADFG Escapement Index) and suggest an intermediate pink harvest in 2013. Additionally, this matrix shows that anomalously low (red: 2000, 2006, 2008, 2012) or high (green: 1999, 2001, 2005, 2011) return years always flag 3-5 ecosystem indicators of the respective color signal in each row. For the 2013 forecast, however, no "red" ecosystem indicators were flagged. The Icy Strait temperature index (ISTI) shown in the last column is not significantly correlated with harvest, but is an important secondary parameter to explain the error in the CPUE and harvest regression model. For more details about the SECM pink salmon forecasts, please see: `http://www.afsc.noaa.gov/ABL/MSI/msi_sae_psf.htm`

Implications: Additional evidence from SECM research and other biological or ecosystem indicators suggests a **strong pink salmon harvest in SEAK of 53.8 M fish in 2013**. The strongest indicator for this favorable forecast is the 2012 peak juvenile pink salmon CPUE, which was the 4th highest on record. Other ecosystem indicators in 2012 that were significantly correlated (P ¡ 0.05) with SEAK pink salmon harvest (1998-2012) were: 1) a favorable July month of peak seaward

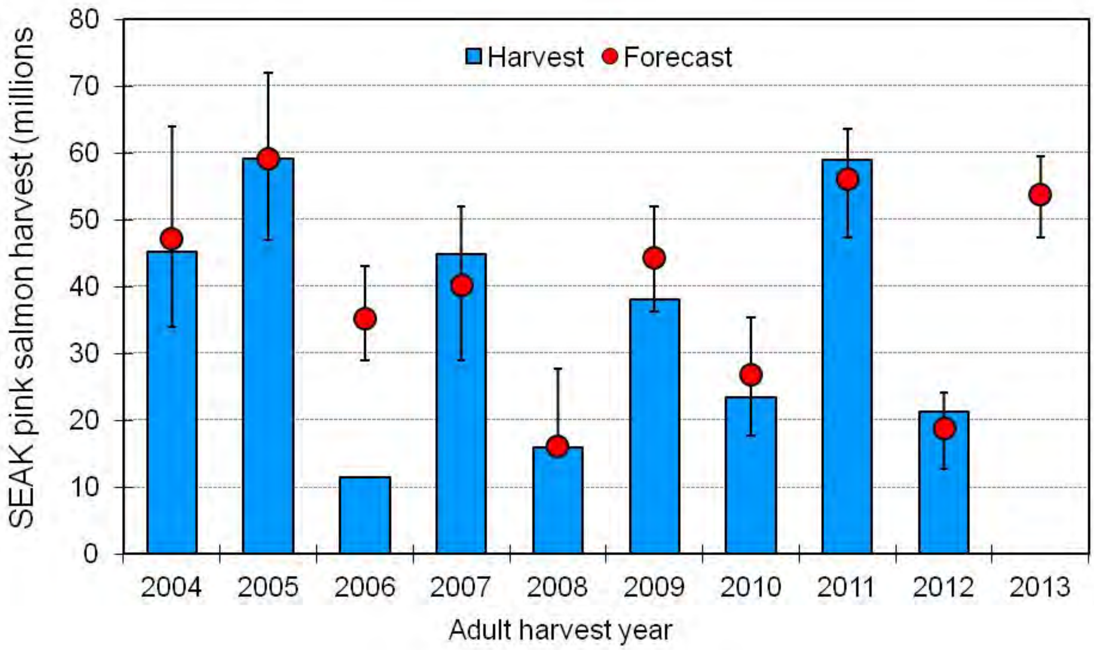

Figure 26: Previous SECM pink salmon forecast model predictions (with 80% confidence intervals) and actual SEAK harvests.

Table 3: The two best SECM pink salmon forecast models for the 2013 SEAK harvest.

2013 SECM pink salmon forecast models	Adj. R^2	AIC_c	P	Prediction for 2013
(1-parameter) Peak CPUE	84.8%	98.1	<0.001	47.8 M (41.5-51.8)
(2-parameter) Peak CPUE+$\mathbf{ISTi_{20m\ temp}}$	91.2%	92.0	<0.001	**53.8 M (46.2-58.4)**

migration; 2) a high North Pacific Index (NPI = 16.7); and 3) a high average percentage of pink salmon (40%) caught among juveniles in June-July trawl hauls. Less favorable ecosystem indicators were a below average ADFG escapement index for the pink salmon parent year (2011) in SEAK and a below average wild fry production in Auke Creek (2012). An additional indicator favoring a good harvest in 2013 was the ocean catch rates of juvenile pink salmon from a research survey downstream from the SECM project, the Gulf of Alaska Integrated Research Project (GOAIRP) conducted offshore of Baranof and Chichagof Islands both west and south of Icy Strait. Compared to the SECM surveys, pink salmon catch data from this project may better represent southern and coastal SEAK pink salmon stocks, and higher juvenile pink catches in 2012 than in 2011 suggest a higher harvest of these stocks in 2013 than in 2012.

Given the ecosystem conditions and SECM metrics sampled in 2012, the two best SECM forecast models for the 2013 SEAK pink salmon harvest are shown below in Table 3. Each forecast model value has an 80% bootstrap confidence interval shown in parentheses. The 2-parameter model is the best fit predictor for the relationship of the 16-year time series of SECM data parameters with subsequent SEAK pink salmon harvests from 1998 to 2012, based on the R^2 and AICc.

Brood year (BY)		BY +1					BY	BY +1	BY +1
Adult pink salmon return year	SE pink harvest (response variable)	Ocean entry year	Juvenile peak pink CPUE June or July	Peak seaward migration month	North Pacific Index (June, July, Aug)	% pink in trawl hauls average June-July	Adult pink escapement index for SEAK	Auke Creek fry outmigration (1,000s) Lat 58° N	Upper 1-20 m avg. Icy Strait temp. "ISTI" May-Aug
	ADFG	$SECM_{year}$	NOAA	NOAA	CGD	NOAA	ADFG	NOAA	NOAA
1998	42.5	1997	2.5	July	15.6	12%	18.1	31.1	9.5
1999	77.8	1998	5.6	June	18.1	57%	14.8	60.8	9.6
2000	20.2	1999	1.6	July	15.8	8%	14.3	53.5	9.0
2001	67.0	2000	3.7	July	16.9	18%	27.3	132.1	9.0
2002	45.3	2001	2.9	July	16.8	19%	10.8	61.5	9.4
2003	52.5	2002	2.8	July	15.6	14%	18.6	150.1	8.6
2004	45.3	2003	3.1	July	16.1	24%	16.6	95.1	9.8
2005	59.1	2004	3.9	June	15.1	29%	20.0	169.6	9.7
2006	11.6	2005	2.0	Aug	15.5	19%	15.7	87.9	10.3
2007	44.8	2006	2.6	June	17.0	30%	19.9	65.9	8.9
2008	15.9	2007	1.2	Aug	15.7	9%	10.2	81.9	9.3
2009	38.0	2008	2.5	Aug	16.1	14%	17.6	117.6	8.3
2010	23.4	2009	2.1	Aug	15.1	22%	9.5	34.8	9.6
2011	58.5	2010	3.7	June	17.6	66%	12.7	121.6	9.6
2012	20.7	2011	1.4	Aug	15.7	21%	11.2	30.9	8.9
2013	53.8?	2012	3.2	July	16.7	40%	14.3	61.8	8.7
Pearson correlation "r"			0.93	-0.78	0.65	0.59	0.52	0.46	-0.06
P-value (*= significant @ <0.05)			0.00*	0.00*	0.01*	0.02*	0.05*	0.09	0.84

Figure 27: Matrix of ecosystem metrics considered for pink salmon forecasting. The ranges of values below each metric are color-coded, with the highest values in green, intermediate values in yellow, and the lowest values in red. Metrics to the right of the response variable column for SEAK pink harvest are ordered by declining correlation and significance (increasing P-value = declining significance); the corresponding correlation coefficient r and P-value are shown below each metric. Data sources include: the Alaska Department of Fish and Game (A. Piston), NOAA (SECM/Auke Creek-J. Joyce), and Climate and Global Dynamics (J. Hurrell, `http://www.cgd.ucar.edu/cas/jhurrell/indices.data.html`).

Groundfish

Gulf of Alaska Ichthyoplankton Abundance Indices 1981-20011

Contributed by Miriam Doyle[1] and Kate Mier[2]
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Description of index: The Alaska Fisheries Science Center's (AFSC) Ichthyoplankton Database (IchBASE) includes data from collections in the Gulf of Alaska (GOA) from 1972 to the present and with annual sampling from 1981 to 2011, and biennial sampling thereafter. Since 1985 these collections have been part of AFSC's recruitment processes research under the Ecosystems and Fisheries Oceanography Coordinated Investigations Program (EcoFOCI). The primary sampling gear used for these collections is a 60 cm bongo sampler fitted with 333 or 505 m mesh nets and oblique tows are carried out mostly from 100 m depth to the surface or from 10 m off bottom in shallower water (Matarese et al., 2003)(Ichthyoplankton Information System `http://access.afsc.noaa.gov/ichthyo/index.cfm`). Historical distribution of sampling effort extends from the coastal area to the east of Prince William Sound southwestwards along the Alaska Peninsula to Umnak Island, covering coastal, shelf and adjacent deep water but has been most intense in the vicinity of Shelikof Strait and Sea Valley during late spring, May 18-June 7 (Figure 28). From this area and time, a subset of four decades of data has been developed into a time-series of ichthyoplankton species abundance (Doyle et al., 2009) and it is now updated through 2011 (Table 4)).

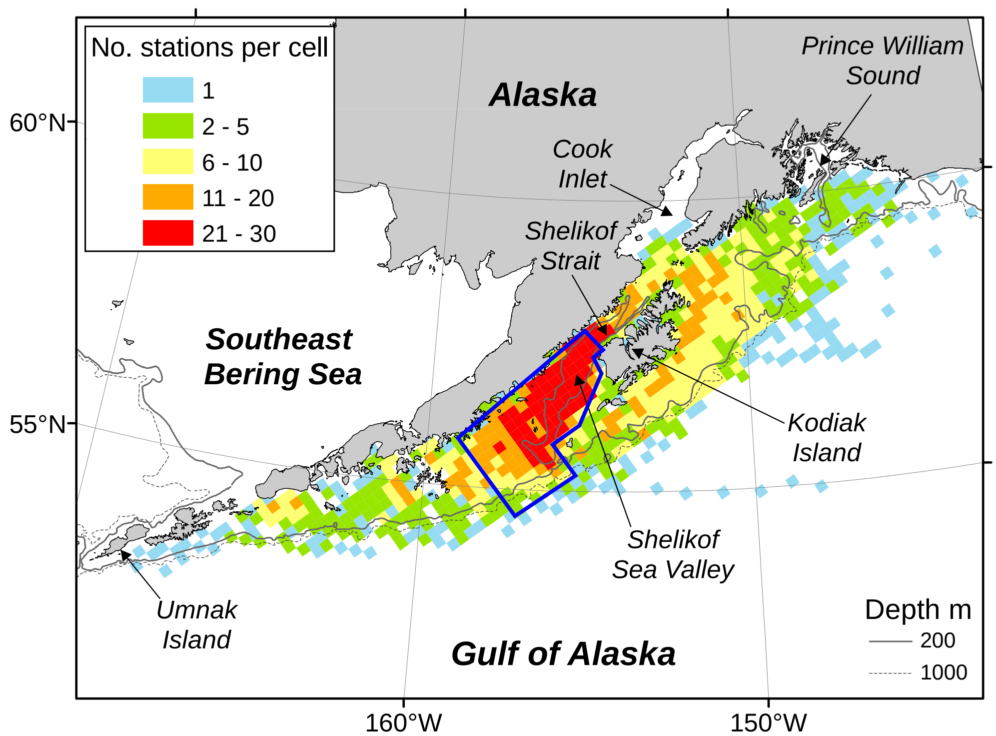

Figure 28: Distribution of ichthyoplankton sampling in the Gulf of Alaska by NOAA's Alaska Fisheries Science Center from 1972 through 2009 using a 60 cm frame bongo net. Sampling effort is illustrated by the total number of stations sampled in 20 km^2 grid cells over these years. A late spring time-series of mean abundance of ichthyoplankton species has been developed for the years 1981-2011, from collections in the polygonal area outlined in blue where sampling has been most consistent during mid-May through early June (Doyle et al., 2009).

Status and trends: Historical trends in late spring abundance are presented for the most abun-

Table 4: Survey schedule and number of stations sampled within the chosen study area (Figure 28) from which the late-spring time-series of larval abundance indices were calculated. Median survey shift = number of days difference (+/-) between a particular year's median sampling survey date and the time-series median survey date (Julian Day 148).

Year	Cruise	Dates	Median survey shift	No. Stations
1981	3SH81	May 23-28	-4	34
	4MF81	May 21-24		59
1982	2DA82	May 23-28	-1	32
1983	1CH83	May 21-28	-2.5	52
1985	2PO85	May 23 - June 1	0	55
1987	3MF87	May 19-23	-6	40
1988	4MF88	May 21 - June 6	2	149
1989	4MF89	May 29 - June 5	4.5	95
1990	4MF90	May 30 - June 5	4	102
1991	4MF91	May 19-24	-6.5	70
1992	4MF92	May 18-26	-4.5	105
1993	5MF93	May 27 - June 1	0.5	74
1994	6MF94	May 24 - June 1	0	98
1995	8MF95	May 22-28	-3	77
1996	8MF96	May 25-31	1	96
1997	8MF97	May 24-30	-1	94
1998	5MF98	May 22-28	-2	95
1999	2WE99	May 25 - June 1	1	67
	5MF99	May 26-31		25
2000	6MF00	May 28 - June 2	3.5	81
2001	3MF01	May 27-31	1	78
2002	4MF02	May 27-30	0	59
2003	5MF03	May 28 - June 1	1.5	72
2004	5MF04	May 23 - June 3	1.5	84
2005	6MF05	May 22 - June 3	0	85
2006	4MF06	May 22 - June 1	-1	81
2007	5MF07	May 20-28	-4	79
2008	4DY08	May 24-30	-1	82
2009	4DY09	May 28 - June 6	4.5	83
2010	3DY10	May 23-28	-1	83
2011	2DY11	June 2-7	8.5	51
Total	Total	Range		Total
27	29	May 18 - June 7		2203

dant larval taxa in the GOA, representing commercially and ecologically important species (Figure 29). The time-series extends from 1981 through 2011 with no data for 1984 and 1986. Mean abundance values are normalized over the time-series. For all taxa except rockfish (*Sebastes* spp.), the 2010 and 2011 data points represent values that are moderate deviations from the long term means (Figure 29). These are low to moderate negative anomalies in both years with the exception of walleye pollock and southern rock sole which displayed moderately positive anomalies for 2010, and a slightly positive anomaly for flathead sole in 2011. For rockfish larvae, a moderate positive anomaly in 2010 was followed by a very high positive anomaly in 2011. Trends in abundance of these species (1981-2003) have been explored previously and investigated in relation to time-series of atmospheric and oceanographic variables on both the ocean basin and local scales (Doyle et al., 2009). Coherent patterns and synchronicity in trends were observed among groups of species, and with the extension of the time-series through 2009, these similarities and synchronicities were maintained (**?**) and are described in last year's contribution to the Ecosystem Considerations report.

Factors influencing observed trends: Synchronies and similarities in larval abundance trends, and in GAM model-generated links to time-series of environmental variables (1981-2003), reflect early life history variation among species (Doyle et al., 2009). Similarities in response to environmental forcing were apparent among species that display similarities in patterns of early life history exposure to the environment. For instance, the deepwater spawners, northern lampfish, arrowtooth flounder, and Pacific halibut, were most abundant in the study area during the 1990s, in association with enhanced wind-driven onshore and alongshore transport. Years of high abundance for the late winter to early spring shelf spawners Pacific cod, walleye pollock, and northern rock sole were associated with cooler winters and enhanced alongshore winds during spring. High larval abundance for spring-summer spawning rockfish species and southern rock sole seemed to be favored by warmer spring temperatures later in the time-series.

Further evidence of environmental exposure-response connections among GOA species is provided by a recent study that incorporates multiple early life history characteristics into a comparative analysis of early ontogeny exposure patterns (**?**). Species groups that emerged from this analysis were reflected in the NMDS ordination of the 1981-2009 larval abundance time-series.

With the current extension of the ichthyoplankton time-series through 2011, investigations continue both in terms of documenting species trends and identifying consistency or variability in the established relationships between species (and groups of species) and aspects of the GOA environment. In addition to larval abundance, larval mean lengths and length frequencies have been synthesized for selected species to identify possible phenological shifts in both peak spawning and larval hatching, or variation in larval growth rates, over the time-series (**?**). Although there is a potential confounding factor from variation in timing of surveys over the time-series, the shift in the median survey date is less than a week except for 2011 when it was +8.5 days and all sampling was carried out in early June.

Implications: Understanding ecological connections between the early ontogeny stages of fish and the pelagic environment contributes to the evaluation of vulnerability and resilience among GOA species' early life history patterns to fluctuating oceanographic conditions. Analyses of these time-series also provides crucial information for the identification of environmental indicators that may have a broad-spectrum effect on multiple species early life history stages, as well as those that may be more species-specific in exerting control on early life history survival. Ongoing research addresses the hypothesis that we can utilize similarities in reproductive and early life history characteristics among species to identify: (1) ecologically determined species groups that are pre-disposed to re-

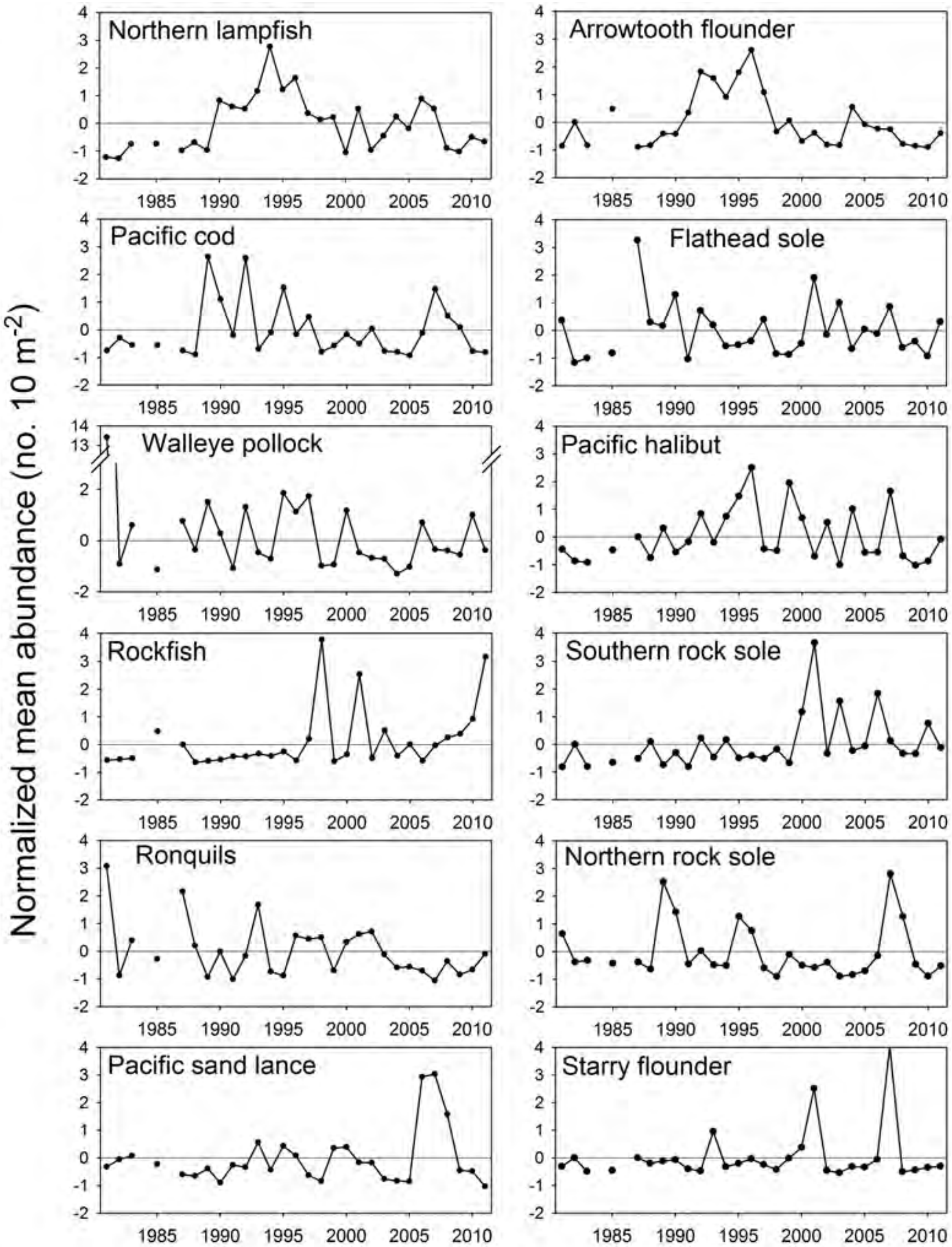

Figure 29: Interannual variation in late spring larval fish abundance for the most abundant species in the Gulf of Alaska. For each year, the larval abundance index is expressed as the log10 of mean abundance (no. 10 m^{-2}+1) standardized by the time-series mean and standard deviation.

spond to environmental forcing in similar ways, and (2) plausible environmental predictors of early life history aspects of recruitment variation. The decrease in sampling frequency of GOA ichthyoplankton (from annual to biennial) is unfortunate as this is one of very few annual ichthyoplankton abundance time-series in the world that extends beyond 25 years. In association with climate and ocean time-series it can illuminate early life history mechanisms that influence recruitment, as well as provide critical information on likely response patterns among species to environmental fluctuations in the GOA.

Trends in Groundfish Biomass and Recruits per Spawning Biomass

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Last updated: October 2011

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Bering Sea Groundfish Condition

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Update on eastern Bering Sea Winter Spawning Flatfish Recruitment and Wind Forcing

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Table 5: Pearson's correlation coefficient relating the temperature change index to subsequent estimated year class strength of pollock (Age-x+1). Bold values are statistically significant ($p < 0.05$).

	Correlations					
TC Index Pollock	t Age-1	t+1 Age-2	t+2 Age-3	t+3 Age-4	t+4 Age-5	t+5 Age-6
1964-2012	**0.405**	**0.394**	**0.367**	**0.302**	**0.305**	**0.277**
1995-2012	**0.451**	**0.449**	**0.457**	**0.455**	**0.642**	**0.613**

Pre- and Post-Winter Temperature Change Index and the Recruitment of Bering Sea Pollock

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Description of index: The temperature change (TC) index is a composite index for the pre- and post-winter thermal conditions experienced by pollock (*Theragra chalcogramma*) from age-0 to age-1 in the eastern Bering Sea (Martinson et al., 2012). The TC index (year t) is calculated as the difference in the average monthly sea surface temperature in June (t) and August (t-1) (Figure 30) in an area of the southern region of the eastern Bering Sea (56.2°N to 58.1°N latitude by 166.9°W to 161.2°W longitude). Time series of average monthly sea surface temperatures were obtained from the NOAA Earth System Research Laboratory Physical Sciences Division website. Sea surface temperatures were based on NCEP/NCAR gridded reanalysis data (Kalnay et al., 1996, data obtained from http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl). Less negative values represent a cool late summer during the age-0 phase followed by a warm spring during the age-1 phase for pollock.

Status and trends: The 2013 TC index value is -3.89. The TC index is positively correlated with subsequent recruitment to age-1 through age-6 for based on abundance estimates from Table 1.21 in Ianelli et al. 2012 (Table 5). This relationship was more statistically significant (p-values were lower) for the age-4, -5 and -6 fish, than for the age-1, -2, and -3 fish for years 1995-2012. However, over the longer time period (1964-2012), the TC index was and more statistically significant for the age-1, age-2, and age-3 fish, than for the older fish (Table 5).

Factors causing observed trends: The age-0 pollock are more energy-rich in a year with a cooler late summer (Coyle et al., 2011; Heintz et al., 2013). Warmer spring temperatures lead to an earlier ice retreat, a later oceanic and pelagic phytoplankton bloom, and more food in the pelagic waters at an optimal time for use by pelagic species (Hunt et al., 2002, 2011; Coyle et al., 2011). Colder later summers during the age-0 phase followed by warmer spring temperatures during the age-1 phase are assumed favorable for the survival of pollock from age-0 to age-1.

Implications: In 2011, the TC index value of -4.23 was slightly above the long term average of

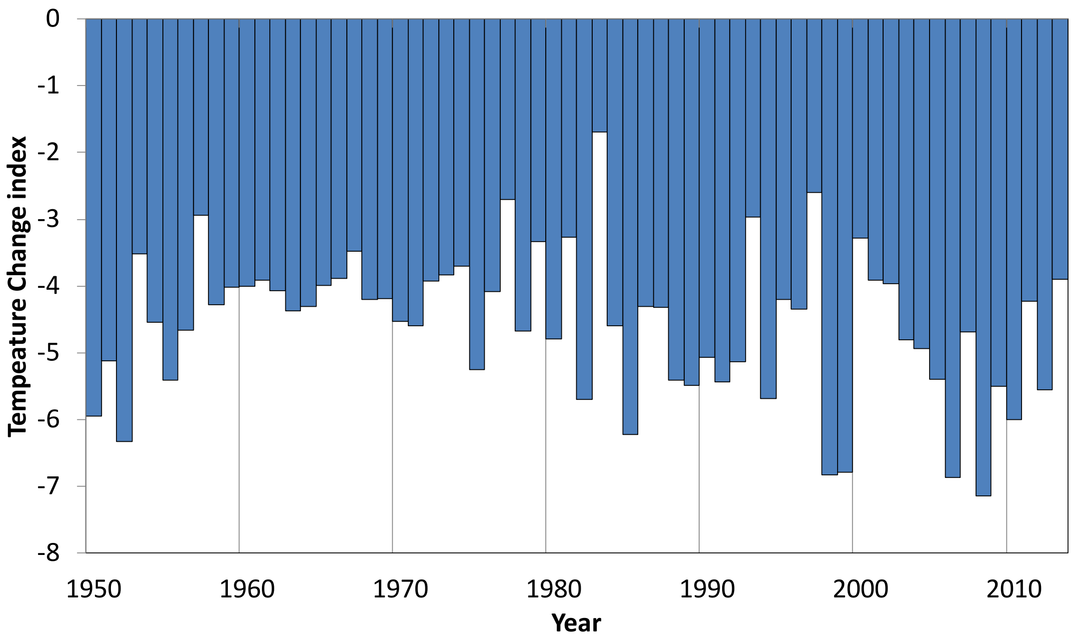

Figure 30: The Temperature Change index value from 1950-2013.

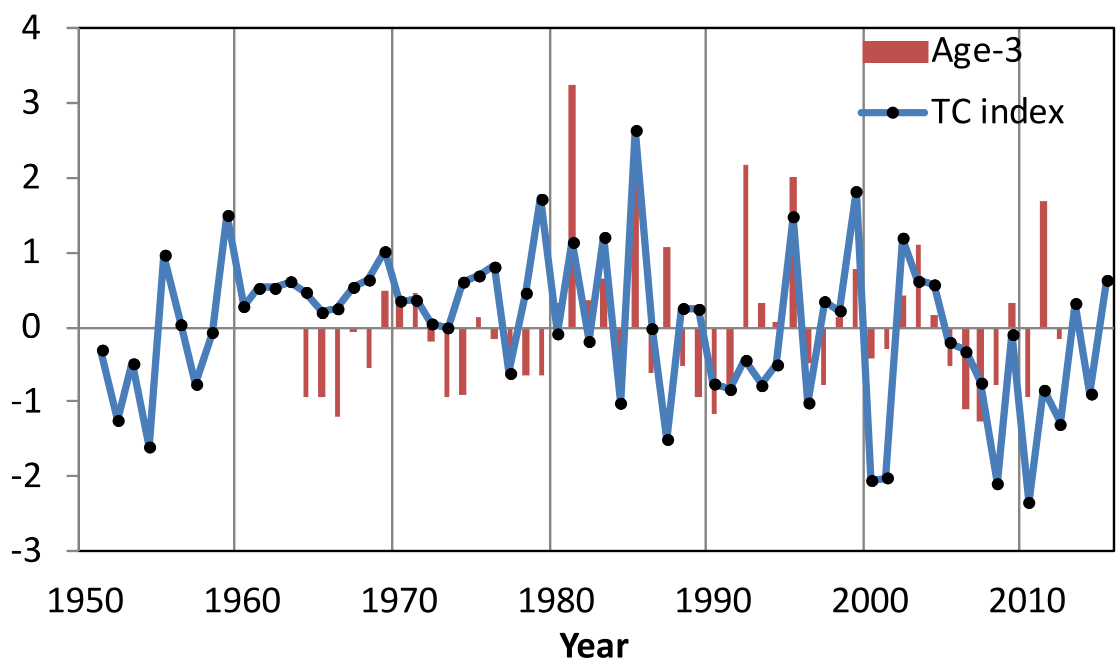

Figure 31: Normalized times series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t).

-4.58, therefore we expect slightly higher than average numbers of pollock to survive to age-3 in 2013 (Figure 30). In the future, the TC values in 2012 (TC=-5.56) and 2013 (TC=-3.89) indicate below average abundances of age-3 pollock in 2014 and above average abundances of age-3 pollock in 2015 (Figure 31).

Distribution of Rockfish Species in Gulf of Alaska and Aleutian Islands Trawl Surveys

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Last updated: October 2012

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Benthic Communities and Non-target Fish Species

Spatial Variability of Catches in Bering Sea and Gulf of Alaska Crab Fisheries

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Bering Sea/Aleutian Islands King and Tanner Crab Stocks

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Miscellaneous Species - Eastern Bering Sea

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ADF&G Gulf of Alaska Trawl Survey

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Description of index: The Alaska Department of Fish and Game conducts an annual trawl survey for crab and groundfish in Gulf of Alaska targeting areas of crab habitat around Kodiak Island, the Alaska Peninsula, and the Eastern Aleutian Islands (Spalinger, 2013). While the survey covers a large portion of the central and western Gulf of Alaska, results from Kiliuda and Ugak Bays (inshore) and the immediately contiguous Barnabas Gully (offshore) (Figure 32) are broadly representative of the survey results across the region. These areas have been surveyed annually since 1984, but the most consistent time series begins in 1988. Standardized anomalies, a measure of departure from the mean, for the survey catches from Kiliuda and Ugak Bays, and Barnabas Gully were calculated and plotted by year for selected species (arrowtooth flounder Atheresthes stomias, flathead sole Hippoglosoides elassodon, Tanner crab Chionoecetes bairdi, Pacific cod Gadus macrocephalus, and skates) using the method described by Link et al. (2002) (Figure 33). Bottom temperatures for each haul have been recorded since 1990 (Figure 34). **Status and trends:** Arrowtooth flounder,

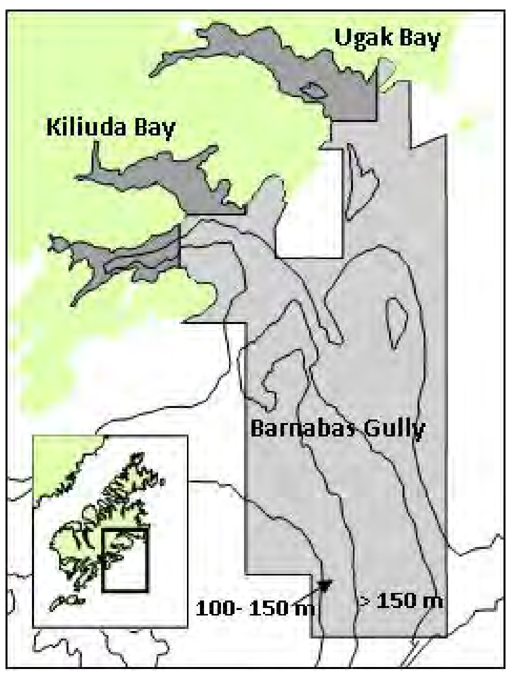


Figure 32: Adjoining survey areas on the east side of Kodiak Island used to characterize inshore (dark gray, 14 stations) and offshore (light gray, 33 stations) trawl survey results.

flathead sole, and other flatfish continue to dominate the catches in the ADF&G trawl survey. A decrease in overall biomass is apparent from 2007 to 2012 from years of record high catches seen from 2002 to 2005 (Figure 35).

Prior to the start of our standard trawl survey in 1988, Ugak Bay was the subject of an intensive seasonal trawl survey in 1976-1977 (Blackburn 1977). Today, the Ugak Bay species composition

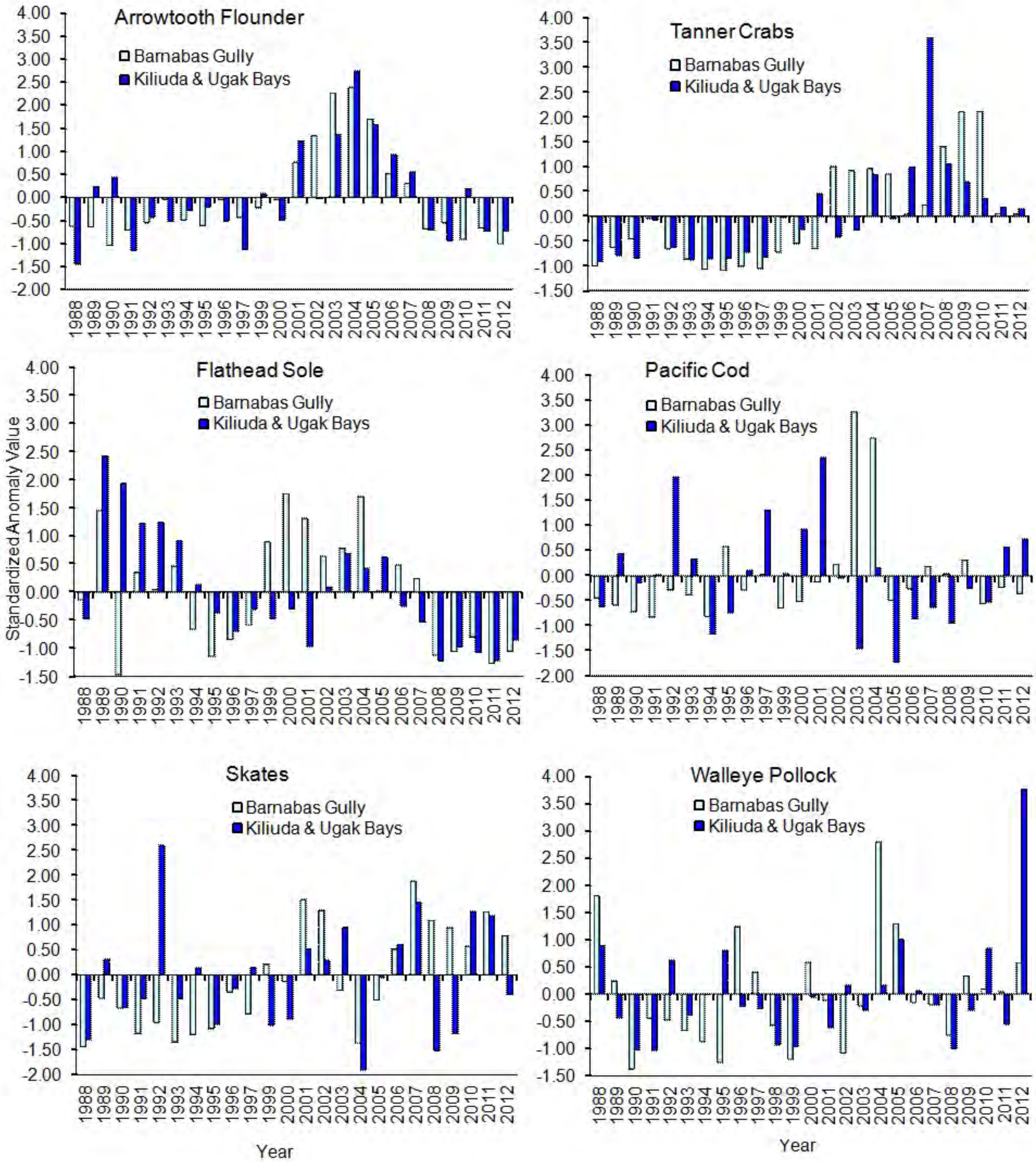


Figure 33: A comparison of standardized anomaly values for selected species caught from 1988-2012 in Barnabas Gully and Kiliuda and Ugak Bays during the ADF&G trawl surveys.

is markedly different than in 1976. Red king crabs Paralithodes camtschaticus were the main component of the catch in 1976-1977, but now are nearly non-existent. Flathead sole, skate, and gadid catch rates have all increased roughly 10-fold. While Pacific cod made up 88% and walleye pollock 10% of the gadid catch in 1976-1977, catch compositions have reversed in 2012 with Pacific

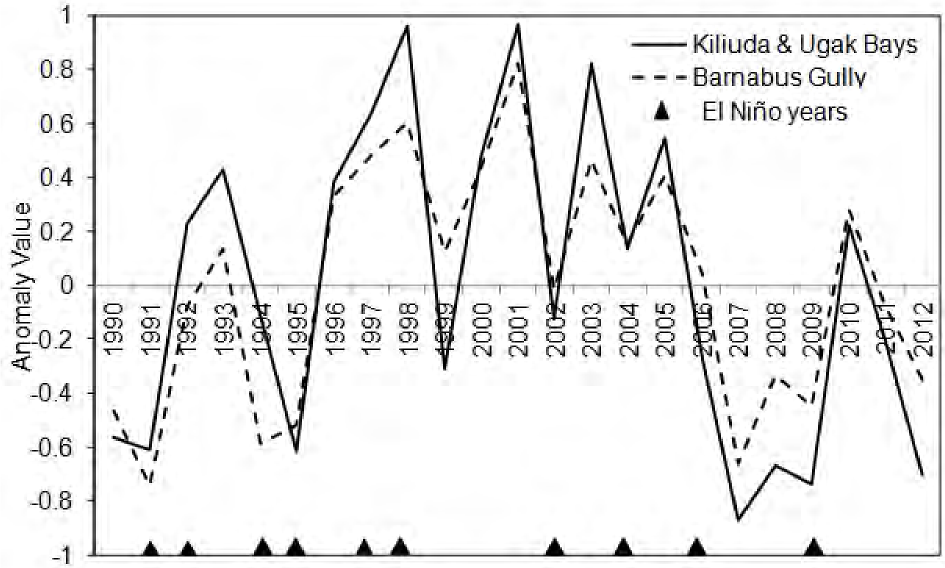


Figure 34: Bottom temperature anomalies recorded from the ADF&G trawl survey for Barnabas Gully and Kiliuda and Ugak Bays from 1990 to 2012, with corresponding El Niño years represented.

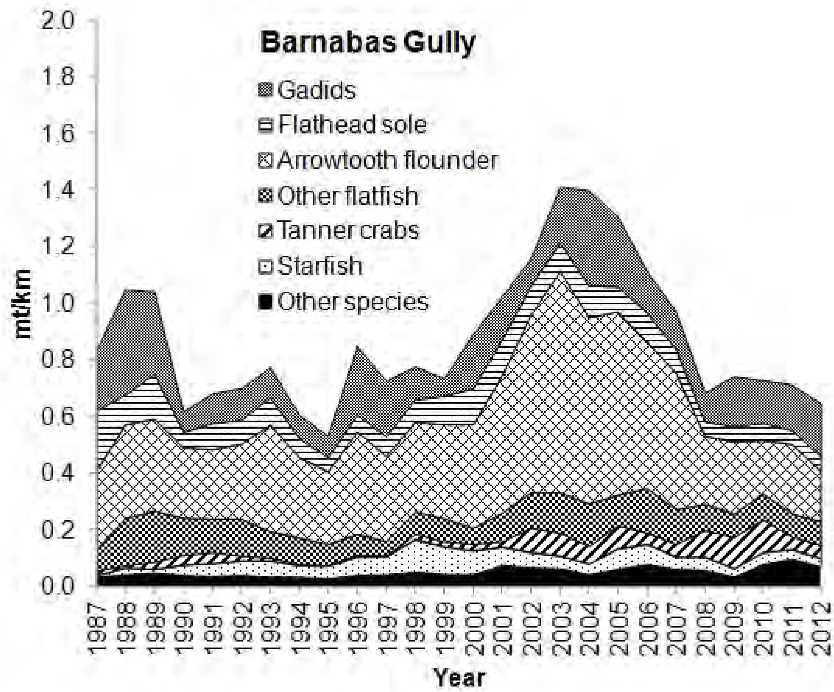
cod making up 8% of catch and walleye pollock 92%. In 2012, overall gadid catches have slightly decreased in offshore area of Barnabus Gully, but increased in the inshore areas of Kiliuda and Ugak Bays (Figure 35).

In 2012, above average anomaly values for Tanner crabs were recorded for both inshore and offshore areas, while arrowtooth flounder and flathead sole values remain below average (Figure 33). Walleye pollock was well above average for both inshore and offshore areas, while Pacific cod remained above only in the inshore areas.

Temperature anomalies for both inshore, Kiliuda and Ugak Bays and offshore stations, Barnabas Gully, from 1990 to 2012, show similar oscillations with periods of above average temperatures corresponding to the strong El Niño years (1997-1998; Figure 34; `http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html`). Cooler temperatures are apparent in 2011 and 2012.

Factors influencing observed trends: It appears that significant changes in volume and composition of the catches on the east side of Kodiak are occurring, but it is unknown to what extent predation, environmental changes, and fishing effort are contributing. The lower overall catch from 1993 to 1999 (Figure 35) may be a reflection of the greater frequency of El Niño events on overall production while the period of less frequent El Niño events, 2000 to 2006, corresponds to years of greatest production and corresponding catches. Lower than average temperatures have been recorded from 2007 to 2009 along with decreasing overall abundances. This may indicate a possible lag in response to changing environmental conditions or some other factors may be affecting abundance that are not yet apparent.

Implications: Although trends in abundance in the trawl survey appear to be influenced by major oceanographic events such as El Niño, local environmental changes, predation, movements, and fishery effects may influence species specific abundances and need to be studied further. Monitoring these trends is an important process used in establishing harvest levels for state water fisheries.



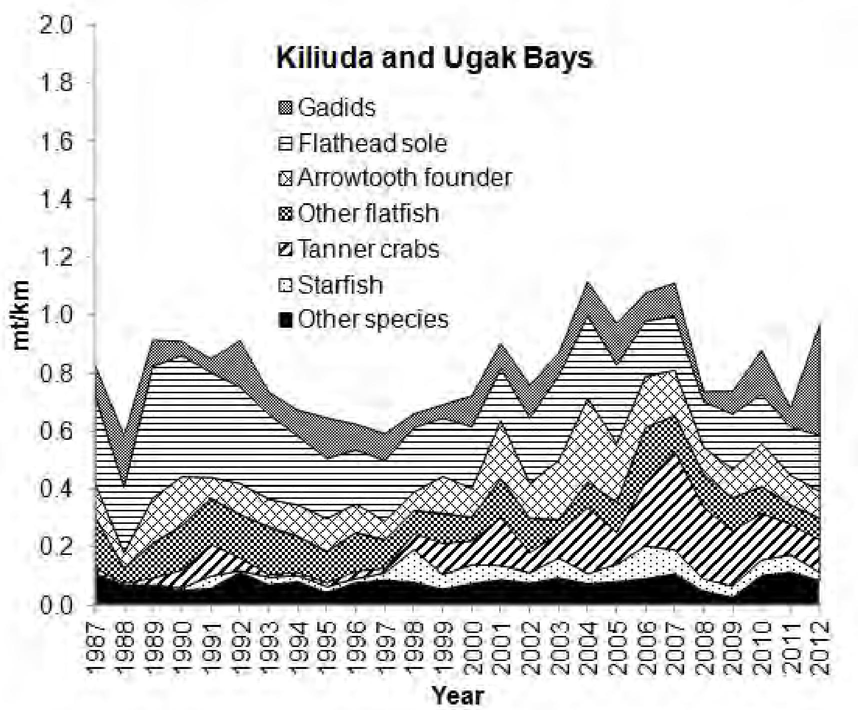


Figure 35: Total catch per km towed (mt/km) during the ADF&G trawl survey from adjacent areas off the east side of Kodiak Island, 1987 to 2012.

This survey data is used to establish guideline harvest levels of state managed fisheries and supply abundance estimates of the nearshore component of other groundfish species such as Pacific cod and pollock. Decreases in species abundance will most likely be reflected in decreased guideline harvest levels.

Miscellaneous Species - Gulf of Alaska

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Last updated: October 2011

Gulf of Alaska surveys are conducted in alternate odd years. See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Miscellaneous Species - Aleutian Islands

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Aleutian Islands survey are conducted in alternate even years. See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Seabirds

Multivariate Seabird Indices for the Eastern Bering Sea

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See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2011

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Last updated: July 2013

Description of index: This report provides estimates of the numbers of seabirds caught as bycatch in commercial groundfish fisheries in Alaska operating in federal waters of the U.S. Exclusive Economic Zone for the years 2007 through 2012. Fishing gear types represented are demersal longline, pot, pelagic trawl, and non-pelagic trawl. These numbers do not apply to gillnet, seine, troll, or halibut longline fisheries. Data collection on the Pacific halibut longline fishery began in 2013 and will be summarized in the Ecosystem Considerations report in 2014.

Estimates are based on two sources of information, (1) data provided by NMFS-certified Fishery Observers deployed to vessels and floating or shoreside processing plants (**?**), and (2) industry reports of catch and production. The AFSC produced the estimates from 1993-2006 (Fitzgerald et al., 2008). The NMFS Alaska Regional Office Catch Accounting System produced the estimates from 2007-2012 (Cahalan et al., 2010).

Status and trends: Figure 36 depicts seabird bycatch in the groundfish fisheries from 1993 through 2012 using results from the two analytical methods. The 2012 estimated numbers for the combined groundfish fisheries (Table 6) are 40% below the running 5-year average for 2007-2011 of 8,295 birds. Albatross bycatch was reduced in 2012 by 27% compared to the previous 5 years, with the greatest decrease in Laysan (*Phoebastria immutabilis*; 36% reduction) versus black-footed albatross (*P. nigripes*; 11% decline). Northern fulmar (*Fulmaris glacialis*) bycatch remained the highest proportion in the catch at 61%, but was down by 39% compared to the 5-year average and 52% from the year before. Fulmar bycatch has ranged between 45 to 76% of the total seabird bycatch since 2007. Average annual mortality for fulmars since 2007 has been 4,586. However, when compared to estimates of total population size in Alaska of 1.4 million (**?**), this represents an annual 0.33% mortality due to fisheries. However, there is some concern that the mortality could be colony-specific possibly leading to local depletions (**?**). The demersal longline fishery in Alaska typically drives the overall estimated bycatch trends (but see comment regarding trawl estimates below). Bycatch in the longline fishery showed a marked decline beginning in 2002 due to the deployment of streamer lines as bird deterrents. Since then, annual bycatch has remained below 10,000 birds, dropping as low as 3,704 in 2010. Numbers increased to 8,914 in 2011, the second highest in the streamer line era, but fell back to 4,544 in 2012. The increased numbers in 2011 were due to a doubling of the gull (*Larus* spp) numbers (1,084 to 2,206) and a 3-fold increase in fulmars, from 1,782 to 5,848. These species group numbers have decreased in 2012 as well, to 885 and 3,016 respectively.

Albatross bycatch varied annually. The greatest numbers of albatross were caught in 2008. In 2012, 57.0% of albatross bycatch occurred in the GOA (down from 87% in 2011). The GOA typically accounts for 10 to 20% of overall seabird bycatch. Only Laysan albatross were taken in the BSAI; all black-footed albatross were taken in the GOA (along with about 14 Laysan). While the estimated bycatch of black-footed albatross underwent a 4-fold increase in bycatch (44 to 206) between 2010 and 2011, the 2012 estimates are about 11% under the long-term average of 153 birds per year. Although the black-footed albatross is not endangered (unlike its relative, the short-tailed albatross), it is considered a Bird of Conservation Concern by the U.S. Fish & Wildlife Service. This designation means that without additional conservation actions, these birds of concern are likely to become candidates for listing under the Endangered Species Act. Of special interest is the endangered short-tailed albatross (*Phoebastria albatrus*). Since 2003, bycatch estimates were above zero only in 2010 and 2011, when 2 birds and 1 bird were incidentally hooked respectively,

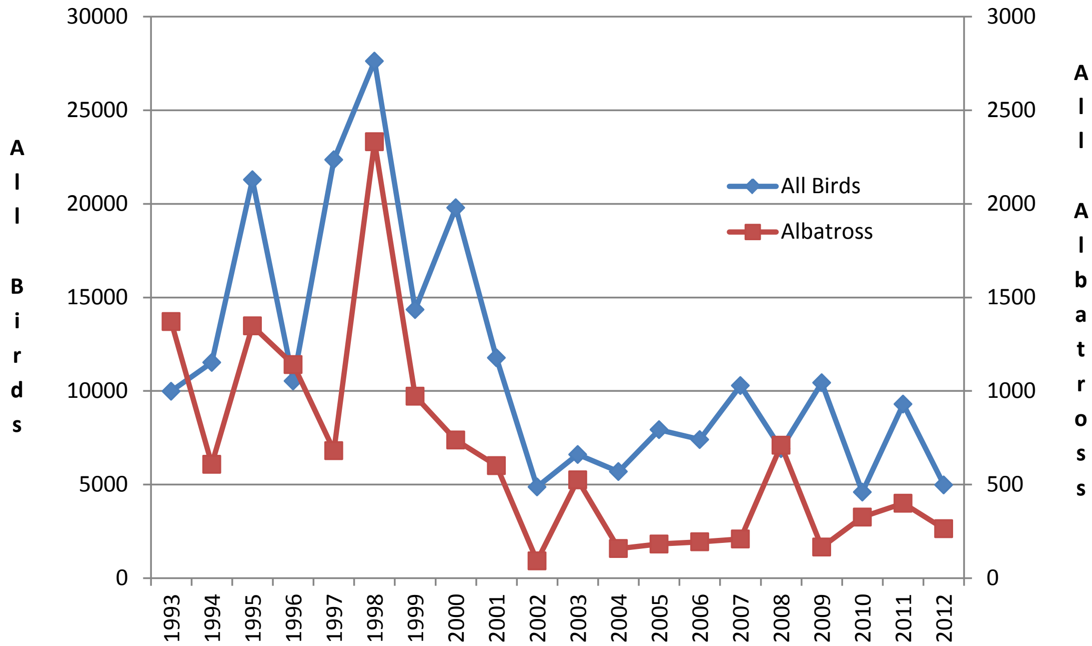

Figure 36: Seabird bycatch in Alaskan groundfish fisheries, all gear types combined, 1993 to 2012. Total estimated bird numbers are shown in the left-hand axis while estimated albatross numbers are shown in the right-hand axis

resulting in estimated takes of 15 and 5 birds. This incidental take occurred in the Bering Sea area. No observed takes occurred in 2012. The expected incidental take, 4 birds every two years since the Biological Opinion was revised in 2003, totals to 20 observed takes while realized observed take has been 3 birds.

Factors influencing observed trends: The marked decline in overall numbers of birds caught after 2002 (Figure 36 reflects the increased use of seabird mitigation devices. A large portion of the freezer longline fleet adopted these measures in 2002, followed by regulation requiring them for the rest of the fleet beginning in February 2004. There are many factors that may influence annual variation in bycatch rates, including seabird distribution, population trends, prey supply, and fisheries activities. Work has continued on developing new and refining existing mitigation gear (Dietrich and Melvin, 2008).

The longline fleet has traditionally been responsible for about 91% of the overall seabird bycatch in Alaska, as determined from the data sources noted above. However, standard observer sampling methods on trawl vessels do not account for additional mortalities from net entanglements, cable strikes, and other sources. Thus, the trawl estimates are biased low (Fitzgerald et al., in prep). For example, the 2010 estimate of trawl-related seabird mortality is 823, while the additional observed mortalities (not included in this estimate and not expanded to the fleet) were 112. Observers now record the additional mortalities they see on trawl vessels and the AFSC Seabird Program is seeking funds to support an analyst to work on how these additional numbers can be folded into an overall estimate. The challenge to further reduce seabird bycatch is great given the rare nature of the event. For example, Dietrich and Fitzgerald (2010) found in an analysis of 35,270 longline sets from 2004 to 2007 that the most predominant species, northern fulmar, only occurred in 2.5 of all sets. Albatross, a focal species for conservation efforts, occurred in less than 0.1 of sets. However,

Table 6: Total **estimated** seabird bycatch in Alaskan groundfish fisheries, all gear types and Fishery Management Plan areas combined, 2007 through 2012. Note that these numbers represent extrapolations from observed bycatch, not direct observations. See text for estimation methods.

Species/Species Group	2007	2008	2009	2010	2011	2012
Unidentified Albatross	16	0	0	0	0	0
Short-tailed Albatross	0	0	0	15	5	0
Laysan Albatross	17	420	114	267	189	128
Black-footed Albatross	176	290	52	44	206	136
Northern Fulmar	4,581	3,426	7,921	2,357	6,214	3,016
Shearwater	3,602	1,214	622	647	199	510
Storm Petrel	1	44	0	0	0	0
Gull	1,309	1,472	1,296	1,141	2,208	885
Kittiwake	10	0	16	0	6	5
Murre	7	5	13	102	14	6
Puffin	0	0	0	5	0	0
Auklet	0	3	0	0	0	7
Other Alcid	0	0	105	0	0	0
Other Bird	0	0	136	0	0	0
Unidentified	509	40	166	18	259	284
Total	10,228	6,914	10,441	4,596	9,298	4,997

given the vast size of the fishery, the total bycatch can add up to hundreds of albatross or thousands of fulmars (Table 6).

Implications: It is difficult to determine how seabird bycatch numbers and trends are linked to changes in ecosystem components because seabird mitigation gear is used in the longline fleet. There does appear to be a link between poor ocean conditions and the peak bycatch years, on a species-group basis. Fishermen have noted in some years that the birds appear "starved" and attack baited longline gear more aggressively. In 2008 general seabird bycatch in Alaska was at relatively low levels (driven by lower fulmar and gull bycatch) but albatross numbers were the highest at any time between 2002 and 2012. This could indicate poor ocean conditions in the North Pacific as albatross traveled from the Hawaiian Islands to Alaska. Broad changes in overall seabird bycatch, up to 5,000 birds per year, occurred between 2007 and 2012. This probably indicates changes in food availability rather than drastic changes in how well the fleet employs mitigation gear. A focused investigation of this aspect of seabird bycatch is needed and could inform management of poor ocean conditions if seabird bycatch rates (reported in real time) were substantially higher than normal. In general however, there seems to be a generally decreasing trend since the new estimation procedures began in 2007 indicating no immediate management concern other then continuing our general goal of decreased seabird bycatch.

Marine Mammals

The Marine Mammal Protection Act requires stock assessment reports to be reviewed annually for stocks designated as strategic, annually for stocks where there are significant new information available, and at least once every 3 years for all other stocks. Each stock assessment includes, when available, a description of the stock's geographic range, a minimum population estimate, current population trends, current and maximum net productivity rates, optimum sustainable population levels and allowable removal levels, and estimates of annual human-caused mortality and serious injury through interactions with commercial fisheries and subsistence hunters. The most recent Alaska Marine Mammal stock assessment was released in May 2012 and can be downloaded at `http://www.nmfs.noaa.gov/pr/sars/region.htm`.

Steller Sea Lion (*Eumetopias jubatus*)

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Last updated: October 2010

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Northern Fur Seal (*Callorhinus ursinus*)

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Last updated: October 2011

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Harbor Seals (*Phoca vitulina*)

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See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Arctic Ice Seals: Bearded Seal, Ribbon Seal, Ringed Seal, Spotted Seal

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Last updated: July 2009

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Bowhead Whale (*Balaena mysticetus*)

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Last updated: August 2012

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Ecosystem or Community Indicators

Indicators of Basin-scale and Alaska-wide Community Regime Shifts

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Last updated: August 2013

Description of index: The first and second principal components (PCs) for 64 biology time series from Baja California to the Bering Sea allow basin-scale patterns of biological variability to be monitored (Hare and Mantua, 2000). These data include 36 Alaskan time series (19 from the Gulf of Alaska and 17 from the Bering Sea). Alaskan time series include recruitment estimates for groundfish (n = 15) and herring (n = 3) populations, log-transformed and lagged to cohort year; commercial salmon catches (n = 16), log-transformed and lagged to year of ocean entry; and measures of invertebrate abundance (n = 2). These indices are useful for monitoring possible biological responses to the negative Pacific Decadal Oscillation (PDO)/positive North Pacific Gyre Oscillation (NPGO) conditions that have persisted since 2007/08 (Figure 37). We updated the Hare and Mantua biology time series for 1965-2008 (for the northeast Pacific) and 1965-2009 (for the Alaskan time series). Lags inherent in many time series meant that too many values were missing after 2008 (for the full data set) or after 2009 (for the Alaskan data) for PC analysis to be conducted. However, subsets of time series that could be updated at least through 2010 ($n = 23$ for the northeast Pacific; $n = 13$ for Alaska) allowed PC scores to be estimated through 2011.

Status and trends: *Basin-scale* - There was some evidence of an abrupt change in leading axes of basin-scale biological variability in 2008. Change in the PC1- 2 phase space for all 64 northeast Pacific time series from 2007 to 2008 was significantly greater than the mean for all other year-to-year changes since 1965-66 ($t_{41} = 22.69$, $p < 0.0001$, Figure 38). While the PC scores for more recent years cannot be estimated to assess the persistence of this apparent 2007/08 change in the full data set, PC1 from the reduced data set did not show continuing increases during 2009-11, and PC2 from the reduced data set showed a single anomalous value in 2008, with a return to negative

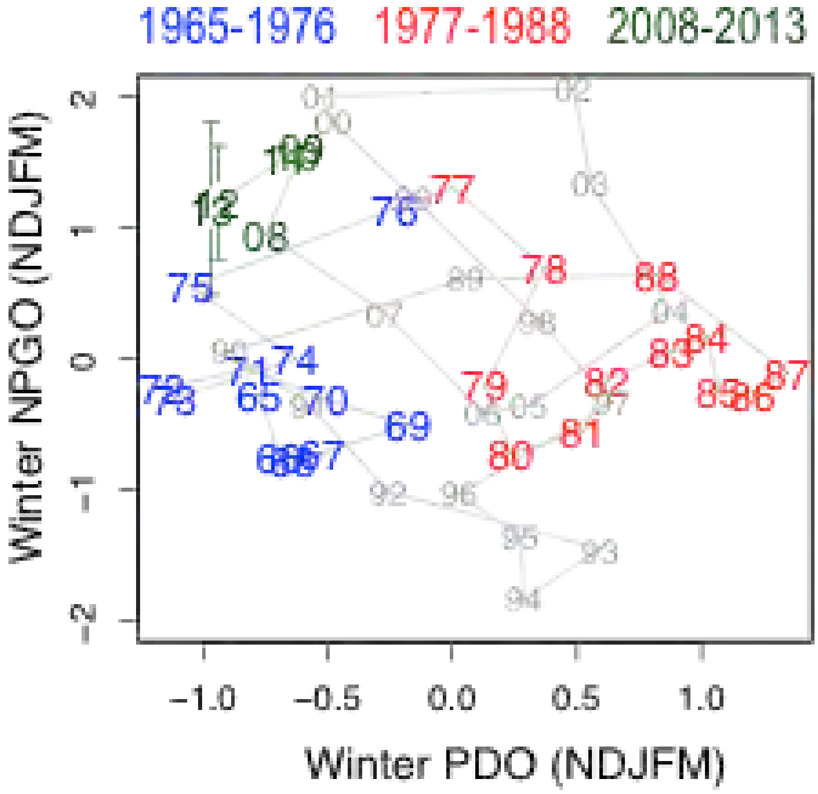

Figure 37: Winter (NDJFM) PDO-NPGO phase space, 1965-2013. Colors highlight recent years (2008-13) and two historical periods of strong PDO influence in the ecosystem (1965-77 and 1978-88). Plotted values are 3-year running means, except for 2013, which is a 2-year mean. Error bars for 2012-13 are 95% CI, reflecting uncertainty associated with estimating 2013 NPGO value.

values during 2009-11 (Figure 38). STARS (sequential t-tests for analysis of regime shifts) found no evidence of statistically significant shifts in either of the reduced basin-wide PC time series during 2008-11 (L = 15 years, H = 6 SD, autocorrelation accounted for with IP4N method, $p > 0.05$).

Alaska-scale - The estimated 2011 value of PC1 for the reduced Alaska-wide data set was above 0, the first positive value in the time series since 1979 (Figure 39a). However, STARS showed no indication of a statistically-significant shift ($p > 0.05$), so these data do not show support for a recent change in this axis of variability. PC1 from the reduced data set is strongly correlated with PC1 from the full data set for the period of overlap (1965-2008, $r = 0.97$), so this result suggests that PC1 for the full data set is likely also not experiencing dramatic change since 2008. PC2 scores from the reduced data set did show a significant shift to more negative values in 2010 (STARS, $P = 0.002$, Figure 39b). However, values of PC2 from the full and reduced data sets are poorly correlated for the years of overlap ($r = 0.48$), so the observed 2010 shift provides weak inference concerning possible change in the second axis of variability across the full community.

Factors influencing observed trends: For the full set of 36 Alaskan time series over 1965-2008, PC1 shows strongest statistical relationships with regional climate change that is independent of basin-scale climate modes, and a weaker relationship with the PDO; PC2 shows strongest statistical relationships with the size of state-wide commercial catches and the NPGO (?). The possibility

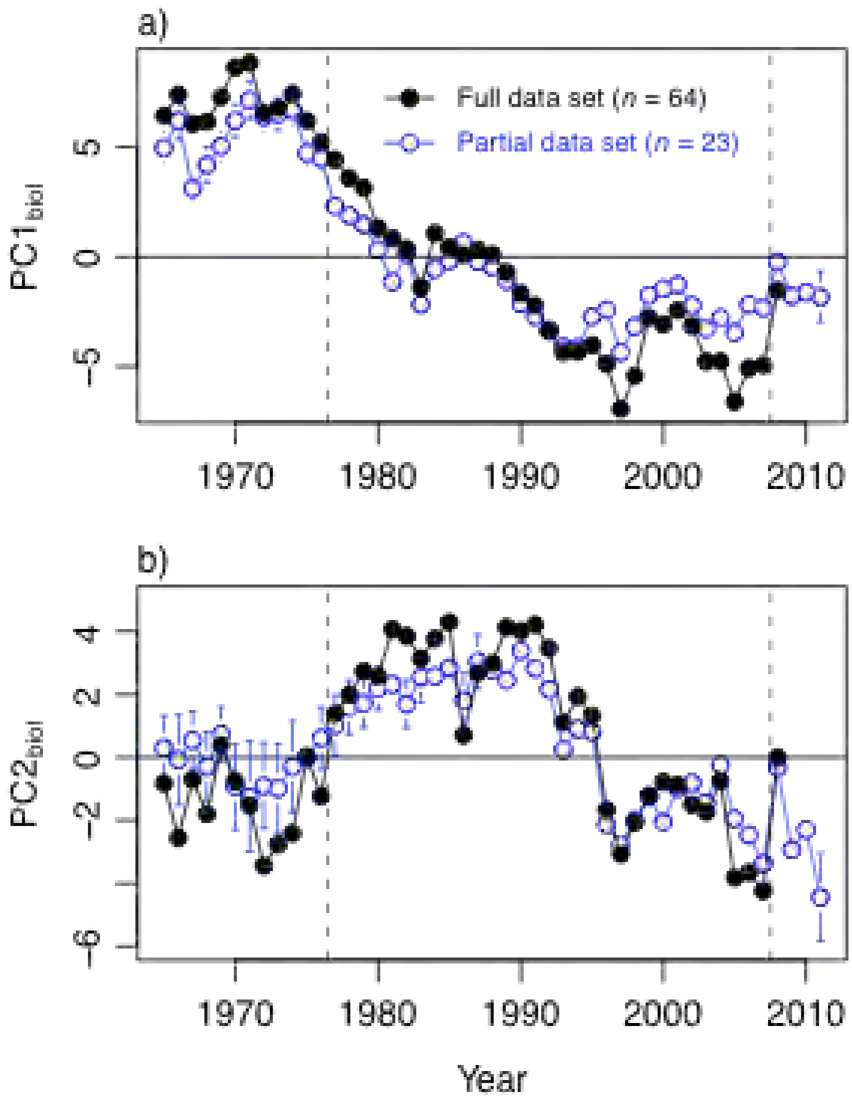

Figure 38: Assessing the evidence for post-2007/08 community-level biological change at the scale of the northeast Pacific. Time series for (a) PC1, and (b) PC2 from complete data set and from a subset of time series that could be updated at least through 2010, which allowed PC scores to be estimated through 2011. Error bars for PC scores calculated from partial data set = 95% CI, and reflect uncertainty associated with estimating missing values. Error bars for PC scores from full data set are omitted for clarity. Dashed vertical lines indicate 1976/77 climate regime shift and possible 2007/08 shift. Redrawn from Litzow and Mueter (in press).

of a biological response to persistent PDO-negative/NPGO-positive conditions since 2007/08 has received recent attention in the literature (Zwolinski and Demer, 2012; **?**; **?**). Based on historical precedents (e.g., the 1940s and 1970s PDO shifts), the consistent sign in both of these climate modes has the potential to produce abrupt community-level change at basin-wide or Alaskan-wide spatial scales, though at this time only PC2 of the reduced Alaskan data set is showing evidence of a recent shift.

Implications: The apparent absence of any recent abrupt shifts in leading axes of basin-wide

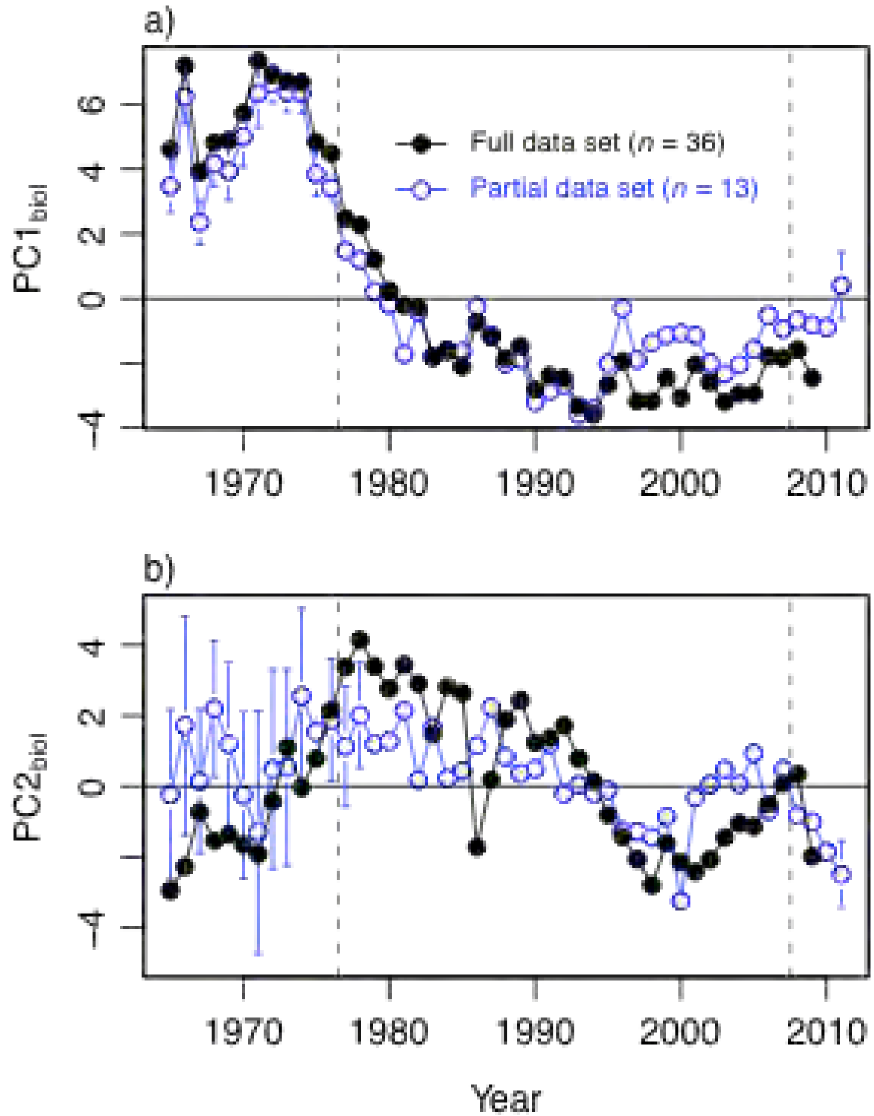

Figure 39: Assessing the evidence for post-2007/08 community-level biological change at the scale of Alaska (Bering Sea and Gulf of Alaska combined). Time series for (a) PC1 and (b) PC2, from complete data set and from a subset of time series that could be updated at least through 2010, which allowed PC scores to be estimated through 2011. Error bars for PC scores calculated from partial data set = 95% CI, and reflect uncertainty associated with estimating missing values. Error bars for PC scores from full data set are omitted for clarity. Dashed vertical lines indicate 1976/77 climate regime shift and possible 2007/08 shift.

biological variability (Figure 38), indicates a continuation of the northeast Pacific ecosystem states that have existed over recent decades (Hare and Mantua, 2000; **?**). PC1 for Alaskan data tracks the change from abundant crustaceans to abundant salmon and groundfish that occurred in the 1980s, and there is currently no indication of abrupt change in the community state tracked by this PC (Fig. 3a). The shift to more negative values for PC2 of the restricted Alaskan data suggests a trend of increases in Bering Sea jellyfish abundance and Pacific cod recruitment, increasing pink salmon catches in central and southeast Alaska and increasing coho salmon catches in southeast; and decreases Gulf of Alaska shrimp catches and decreases in the catch of coho salmon in western and central Alaska and sockeye salmon in southeast. Determining the persistence of the apparent change in PC2, and whether it indicates change in the second axis of variability for the larger community, as tracked by the full set of Alaskan time series, will require further years of observation.

Total Catch-Per-Unit-Effort of All Fish and Invertebrate Taxa in Bottom Trawl Surveys

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Last updated: October 2012

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm` **Description of index:**

Status and trends:

Factors influencing observed trends:

Implications:

Biodiversity (Evenness) of the Groundfish and Invertebrate Community for the Eastern Bering Sea Slope

Contributed by Gerald R. Hoff, Kodiak Laboratory, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA
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Last updated: July 2011

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Average Local Species Richness and Diversity of the Groundfish Community

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Combined Standardized Indices of Recruitment and Survival Rate

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Spatial Distribution of Groundfish Stocks in the Eastern Bering Sea

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Ecosystem-Based Management Indicators

Indicators presented in this section are intended to provide either early signals of direct human effects on ecosystem components that might warrant management intervention or to provide evidence of the efficacy of previous management actions. In the first instance, the indicators are likely to be ones that summarize information about the characteristics of the human influences (particularly those related to fishing, such as catch composition, amount, and location) that are influencing a particular ecosystem component.

Ecosystem Goal: Maintain Diversity

Time Trends in Groundfish Discards

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Last updated: August 2013

Description of index: Estimates of discards for 1994-2002 come from NMFS Alaska Region's blend data; estimates for 2003-2012 come from the Alaska Region's catch-accounting system. It should be noted that although these sources provide the best available estimates of discards, the estimates are not necessarily accurate because they are based on visual observations by observers rather than data from direct sampling.

Status and trends: In 1998, the amount of managed groundfish species discarded in federally-managed Alaskan groundfish fisheries dropped to less than 10% of the total groundfish catch in both the Eastern Bering Sea (EBS) and the Gulf of Alaska (GOA) (Figure 40). Discard rates in the Gulf of Alaska have varied over time but were lower on average in 2011 and 2012. Discard rates in the Aleutian Islands (AI) dropped significantly in 1997, trended generally upwards from 1998 through 2003, and have generally declined over the last nine years. As in the EBS and the GOA, both discards and discard rates in the AI are much lower now than they were in 1996.

Factors influencing observed trends: Discards in both the EBS and the GOA are much lower than the amounts observed in 1997, before implementation of improved-retention regulations. These decreases are explained by reductions in the discard rates of pollock and Pacific cod that resulted from regulations implemented in 1998 prohibiting discards of these two species. The decline in discards in both the AI and the EBS in 2008 is largely due to enactment of improved retention/utilization regulations by the North Pacific Fishery Management Council for the trawl head-and-gut fleet.

Implications: The management of discards in commercial fisheries is important for the reason that discards add to the total human impact on the biomass without providing a benefit to the Nation.

Time Trends in Non-Target Species Catch

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Last updated: August 2013

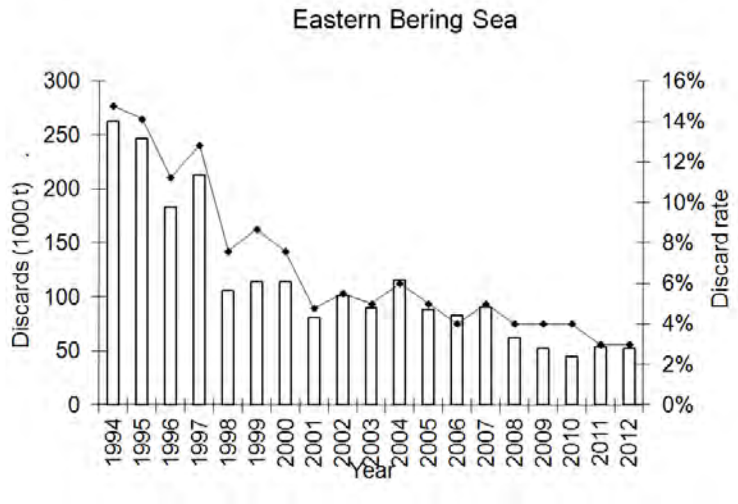
Description of index: We monitor the catch of non-target species in groundfish fisheries in the Eastern Bering Sea (EBS), Gulf of Alaska (GOA) and Aleutian Islands (AI) ecosystems (Figure 41). There are three categories of non-target species:

1. Forage species (gunnels, stichaeids, sandfish, smelts, lanternfish, sand lance)
2. Species associated with Habitat Areas of Particular Concern-HAPC species (seapens/whips, sponges, anemones, corals, tunicates)
3. Non-specified species (grenadiers, crabs, starfish, jellyfish, unidentified invertebrates, benthic invertebrates, echinoderms, other fish, shrimp).

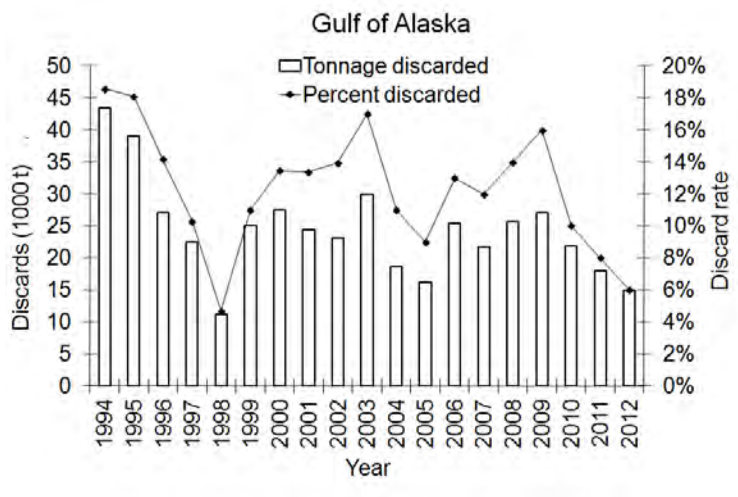
Stock assessments have been developed for all groups in the other species category (sculpins, unidentified sharks, salmon sharks, dogfish, sleeper sharks, skates, octopus, squid), so we do not include trends for "other species" here (see AFSC stock assessment website at `http://www.afsc.noaa.gov/refm/stocks/assessments.htm`).

Total catch of non-target species is estimated from observer species composition samples taken at sea during fishing operations, scaled up to reflect the total catch by both observed and unobserved hauls and vessels operating in all FMP areas. From 1997-2002, these estimates were made at the AFSC using data from the observer program and the NMFS Alaska Regional Office. Catch since 2003 has been estimated using the Alaska Region's new Catch Accounting system. These methods should be comparable. This sampling and estimation process does result in uncertainty in catches, which is greater when observer coverage is lower and for species encountered rarely in the catch.

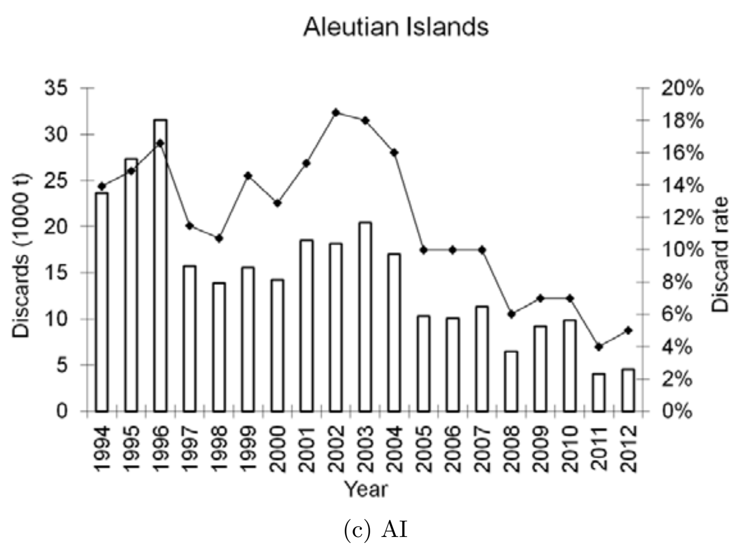
Status and trends: In all three ecosystems, non-specified catch comprised the majority of non-target catch during 1997-2012 (Figure 41). Non-specified catches are similar in the EBS and GOA, but are an order of magnitude lower in the AI. Catches of HAPC biota are highest in the EBS, intermediate in the AI and lowest in the GOA. The catch of forage fish is highest in the GOA, low in the EBS and very low in the AI.



(a) EBS



(b) GOA



(c) AI

Figure 40: Total biomass and percent of total catch biomass of managed groundfish discarded in the EBS, GOA, and AI areas, 1994-2012. (Includes only catch counted against federal TACS)

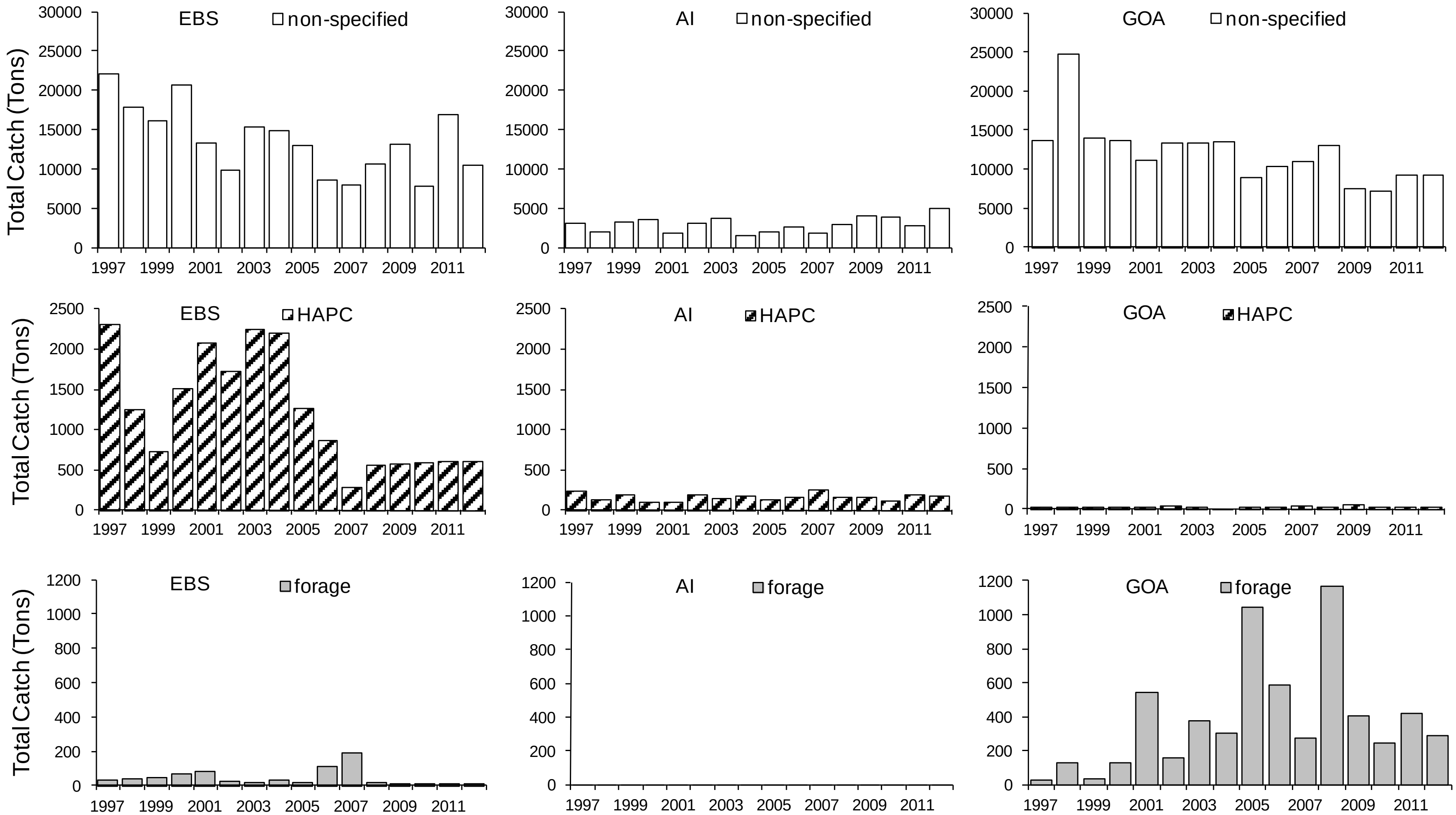


Figure 41: Total catch of non-target species (tons) in the EBS, AI, and GOA groundfish fisheries.

In the EBS, the catch of non-specified species appears to have decreased overall since the late 1990s. Scyphozoan jellyfish, grenadiers and sea stars comprise the majority of the non-specified catches in the EBS. The 2008-2009 and 2010-2011 increase in non-specified catch was driven by jellyfish. Grenadiers (including the Giant grenadier) are caught in the flatfish, sablefish, and cod fisheries. Jellyfish are caught in the pollock fishery and sea stars are caught primarily in flatfish fisheries. HAPC biota catch decreased from 2003 to 2007 and has been generally steady since. Benthic urochordata, caught mainly by the flatfish fishery, comprised the majority of HAPC biota catches in the EBS in all years except 2009-2011, when sponges and sea anemones increased in importance. The catch of forage species in the EBS increased in 2006 and 2007 and was comprised mainly of eulachon that were caught primarily in the pollock fishery; however, forage catch decreased in 2008 and has remained generally low through 2012.

In the AI, the catch of non-specified species shows little trend over time. The non-specified catch declined from 2009 through 2011, then increased to its highest level in 2012. Grenadiers comprise the majority of AI non-specified species catch and are taken in flatfish and sablefish fisheries. HAPC catch has been similarly variable over time in the AI, and is driven primarily by sponges caught in the trawl fisheries for Atka mackerel, rockfish and cod. Forage fish catches in the AI are minimal, amounting to less than 1 ton per year, with the exception of 2000 when the catch estimate was 4 tons, driven by (perhaps anomalous) sandfish catch in the Atka mackerel fishery.

The catch of non-specified species in the GOA has been generally consistent aside from a peak in 1998 and lows in 2009 and 2010. Grenadiers comprise the majority of non-specified catch and they are caught primarily in the sablefish fishery. Sea anemones comprise the majority of the variable but generally low HAPC biota catch in the GOA and they are caught primarily in the flatfish fishery. The catch of forage species has undergone large variations, peaking in 2005 and 2008 and decreasing in 2006-2007 and 2009-2010. The catch of forage species decreased from 2011 to 2012. The main species of forage fish caught are eulachon and they are primarily caught in the pollock fishery.

Factors influencing observed trends: The catch of non-target species may change if fisheries change, if ecosystems change, or both. Because non-target species catch is unregulated and unintended, if there have been no large-scale changes in fishery management in a particular ecosystem, then large-scale signals in the non-target catch may indicate ecosystem changes. Catch trends may be driven by changes in biomass or changes in distribution (overlap with the fishery) or both.

Implications: Catch of non-specified species is highest among the non-target categories and has remained stable or possibly recently declined in the EBS and GOA. Overall, the catch of HAPC and forage species in all three ecosystems is very low compared with the catch of target and non-specified species. HAPC species may have become less available to the EBS fisheries (or the fisheries avoided them more effectively) during the late 2000s. Forage fish may have been more available to fisheries in the GOA during the 2000s.

Ecosystem Goal: Maintain and Restore Fish Habitats

Areas Closed to Bottom Trawling in the EBS/ AI and GOA

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Last updated: August 2013

Description of index: Many trawl closures have been implemented to protect benthic habitat or reduce bycatch of prohibited species (i.e., salmon, crab, herring, and halibut) (Figure 42, Table 7) Some of the trawl closures are in effect year-round while others are seasonal. In general, year-round trawl closures have been implemented to protect vulnerable benthic habitat. Seasonal closures are used to reduce bycatch by closing areas where and when bycatch rates had historically been high.

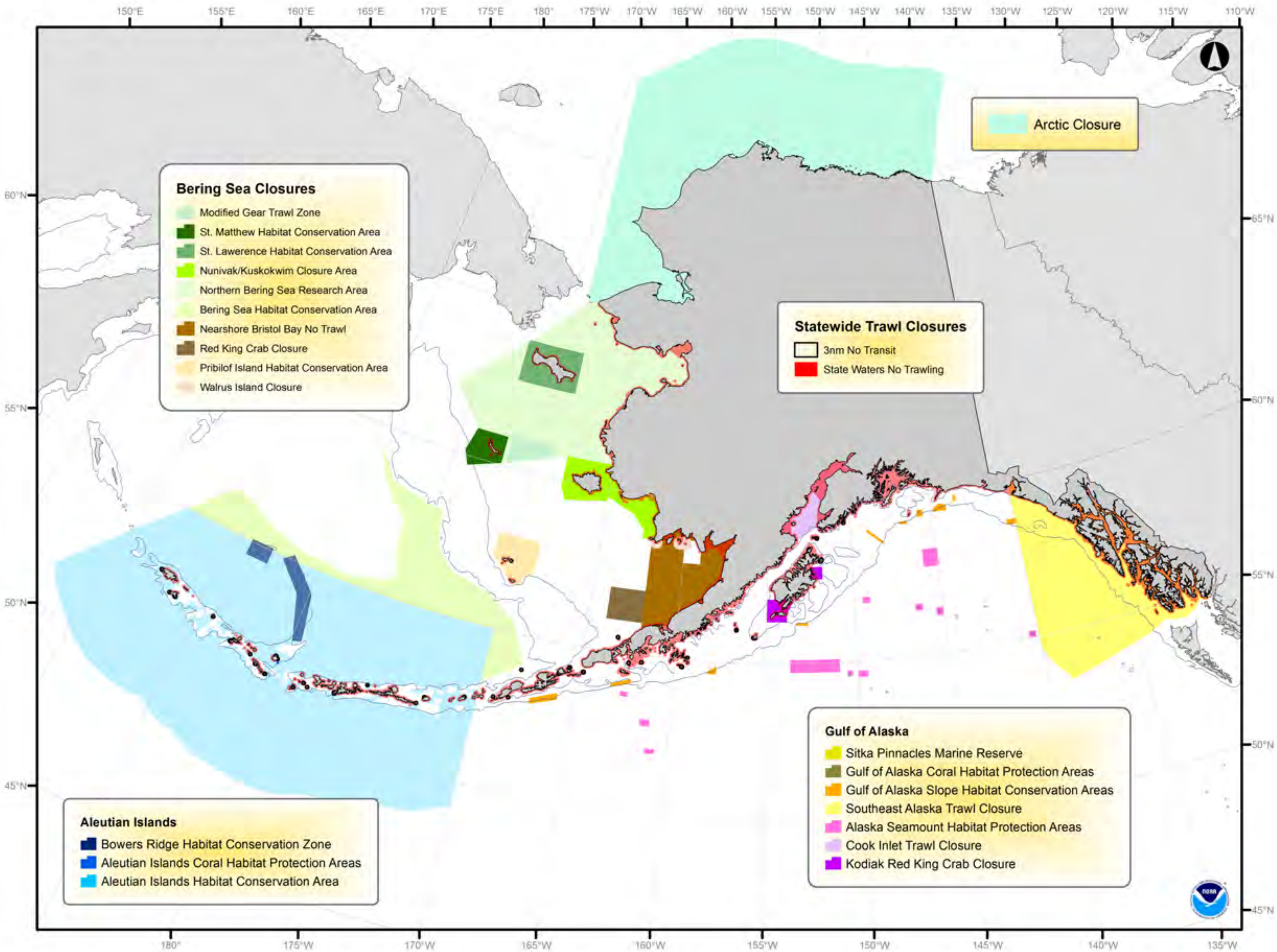

Figure 42: Year-round groundfish closures in the U.S. Exclusive Economic Zone (EEZ) off Alaska, excluding most SSL closures.

Table 7: Groundfish trawl closure areas, 1995-2009. License Limitation Program (LLP); Habitat Conservation Area (HCA); Habitat conservation zone (HCZ).

Area	Year	Location	Season	Area Size	Notes
BSAI	1995	Area 512	year-round	8,000 nm^2	closure in place since 1987
		Area 516	3/15-6/15	4,000 nm^2	closure in place since 1987
		Chum Salmon Savings Area	8/1-8/31	5,000 nm^2	re-closed at 42,000 chum
		Chinook Salmon Savings Area	trigger	9,000 nm^2	closed at 48,000 Chinook
		Herring Savings Area	trigger	30,000 nm^2	trigger closure
		Zone 1	trigger	30,000 nm^2	trigger closure
		Zone 2	trigger	50,000 nm^2	trigger closure
		Pribilofs HCA	year-round	7,000 nm^2	
		Red King Crab Savings Area	year-round	4,000 nm^2	pelagic trawling allowed
		Walrus Islands	5/1-9/30	900 nm^2	12 mile no-fishing zones
		SSL Rookeries	seasonal extensions	5,100 nm^2	20 mile ext., 8 rookeries
	1996	Nearshore Bristol Bay Trawl Closure	year-round	19,000 nm^2	expanded area 512 closure
		C. opilio bycatch limitation zone	trigger	90,000 nm^2	trigger closure
	2000	Steller Sea Lion protections			
		Pollock trawl exclusions	* No trawl all year	11,900 nm^2	*haulout areas include GOA
			No trawl (Jan-June)*	14,800 nm^2	
		Atka Mackerel restrictions	No trawl	29,000 nm^2	
	2006	Essential Fish Habitat			
		AI Habitat Conservation Area	No bottom trawl all year	279,114 nm^2	
		AI Coral Habitat Protection Areas	No bottom contact gear	110 nm^2	all year
		Bowers Ridge HCZ	No mobile bottom tending fishing gear	5,286 nm^2	
	2008	Northern Bering Sea Research Area	No bottom trawl all year	66,000 nm^2	
		Bering Sea HCA	No bottom trawl all year	47,100 nm^2	
		St. Matthews HCA	No bottom trawl all year	4,000 nm^2	
		St. Lawrence HCA	No bottom trawl all year	7,000 nm^2	
		Nunivak/Kuskokwim Closure	No bottom trawl all year	9,700 nm^2	
Arctic	2009	Arctic Closure Area	No Commercial Fishing	148,393 nm^2	
GOA	1995	Kodiak King Crab Protection Zone Type 1	year-round	1,000 nm^2	red king crab closures, 1987
		Kodiak King Crab Protection Zone Type 2	2/15-6/15	500 nm^2	red king crab closures, 1987
		SSL Rookeries	year-round	3,000 nm^2	10 mile no-trawl zones
	1998	Southeast Trawl Closure	year-round	52,600 nm^2	adopted as part of the LLP
		Sitka Pinnacles Marine reserve	year-round	3.1 nm^2	
	2000	Pollock trawl exclusions	No trawl all year	11,900 nm^2*	*haulout areas include BSAI
			No trawl (Jan-June)	14,800 nm^2	
	2006	Essential Fish Habitat			
		GOA Slope Habitat Conservation Area	No bottom trawl all year	2,100 nm^2	
		GOA Coral Habiat Protection Measures	No bottom tending gear	13.5 nm^2	all year
		Alaska Seamount Habitat Protection Measures	No bottom tending gear	5,329 nm^2	all year

Status and trends: Additional measures to protect the declining western stocks of the Steller sea lion began in 1991 with some simple restrictions based on rookery and haulout locations; in 2000 and 2001 more specific fishery restrictions were implemented. In 2001, over 90,000 nm^2 of the Exclusive Economic Zone (EEZ) of Alaska was closed to trawling year-round. Additionally, 40,000 nm^2 were closed on a seasonal basis. State waters (0-3 nmi) are also closed to bottom trawling in most areas. A motion passed the North Pacific Management Council in February 2009 which closed all waters north of the Bering Strait to commercial fishing as part of the development of an Arctic Fishery management plan. This additional closure adds 148,300 nm^2 to the area closed to bottom trawling year round.

In 2010, the Council adopted area closures for Tanner crab east and northeast Kodiak. Federal waters in Marmot Bay are closed year round to vessels fishing with nonpelagic trawl. In two other designated areas, Chiniak Gully and ADF&G statistical area 525702, vessels with nonpelagic trawl gear can only fish if they have 100% observer coverage. To fish in any of the three areas, vessels fishing with pot gear must have minimum 30% observer coverage.

Substantial parts of the Aleutian Islands were closed to trawling for Atka mackerel and Pacific cod (the predominant target species in those areas) as well as longlining for Pacific cod in early 2011 as part of mitigation measures for Steller sea lions. Management area 543 and large sections of 542 are included in this closure.

In 2013, the Council adopted six Areas of Skate Egg Concentrations has Habitat Areas of Particular Concern. No management measures or closures are associated with these HAPCs.

Implications: With the Arctic FMP closure included, almost 65% of the U.S. EEZ of Alaska is closed to bottom trawling.

For additional background on fishery closures in the U.S. EEZ off Alaska, see (Witherell and Woodby, 2005).

Steller Sea Lion closure maps are available here:

`http://www.fakr.noaa.gov/sustainablefisheries/sslpm/atka_pollock.pdf`

`http://www.fakr.noaa.gov/sustainablefisheries/sslpm/pcod_nontrawl.pdf`

`http://www.fakr.noaa.gov/sustainablefisheries/sslpm/cod_trawl.pdf`

Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea

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Last updated: June 2013

Description of index: Fishing gear can affect habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. An estimate of the area of seafloor disturbed by trawl gear may provide an index of habitat disturbance. The area disturbed in the Eastern Bering Sea floor was calculated from observer trawl data each year from 1990-2012. The duration of every trawl haul was multiplied by a fishing effort adjustment as outlined in Appendix B of the January 2005 EFH EIS (`http://www.fakr.noaa.gov/habitat/seis/efheis.htm`). Table B.2-4 in the EIS document lists the adjustment factor for each gear type and vessel class. The adjustment converted trawl haul duration to area disturbed based on the type of trawl gear used (pelagic or bottom) and the vessel length. The adjustment also expanded smaller vessel fishing effort, which has 30% observer coverage, to simulate 100% coverage. Records missing trawl haul duration data and short wire hauls (hauls pulled in but not immediately brought on board) were assigned the average trawl haul duration over all years of 228 minutes (no more than 5% of hauls in any given year needed this adjustment).

An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming that no trawl hauls overlapped spatially. To find the percent disturbed, it was necessary to find the total area of the Eastern Bering Sea being considered (Figure 43a). NMFS reporting areas for the Bering Sea were used as a baseline; however, Norton Sound was excluded because it is beyond the range of many commercially fished groundfish species. The Bering Sea Habitat Conservation boundary was used to exclude areas beyond the shelf break. The resulting total area considered was 742,647 km^2. The percent of area disturbed was estimated in two ways: 1) with no spatial overlap of trawl hauls in a given year, providing an estimate of the maximum potential percent of area disturbed and 2) with spatial overlap of trawl hauls within 400 km^2 cells to limit the disturbance of trawls recorded in a cell to 400 km^2, providing an estimate of potential percent of area disturbed. The average distance of a haul based on recorded start and end locations is 14 km with a standard deviation of 10 km. The cell size was chosen to reflect this spatial resolution of the hauls. Though this cell size allows some overlap of hauls, it still may over estimate the percent area disturbed in a year. The map below shows in what areas trawling disturbances accumulated over various time intervals (Figure 43b).

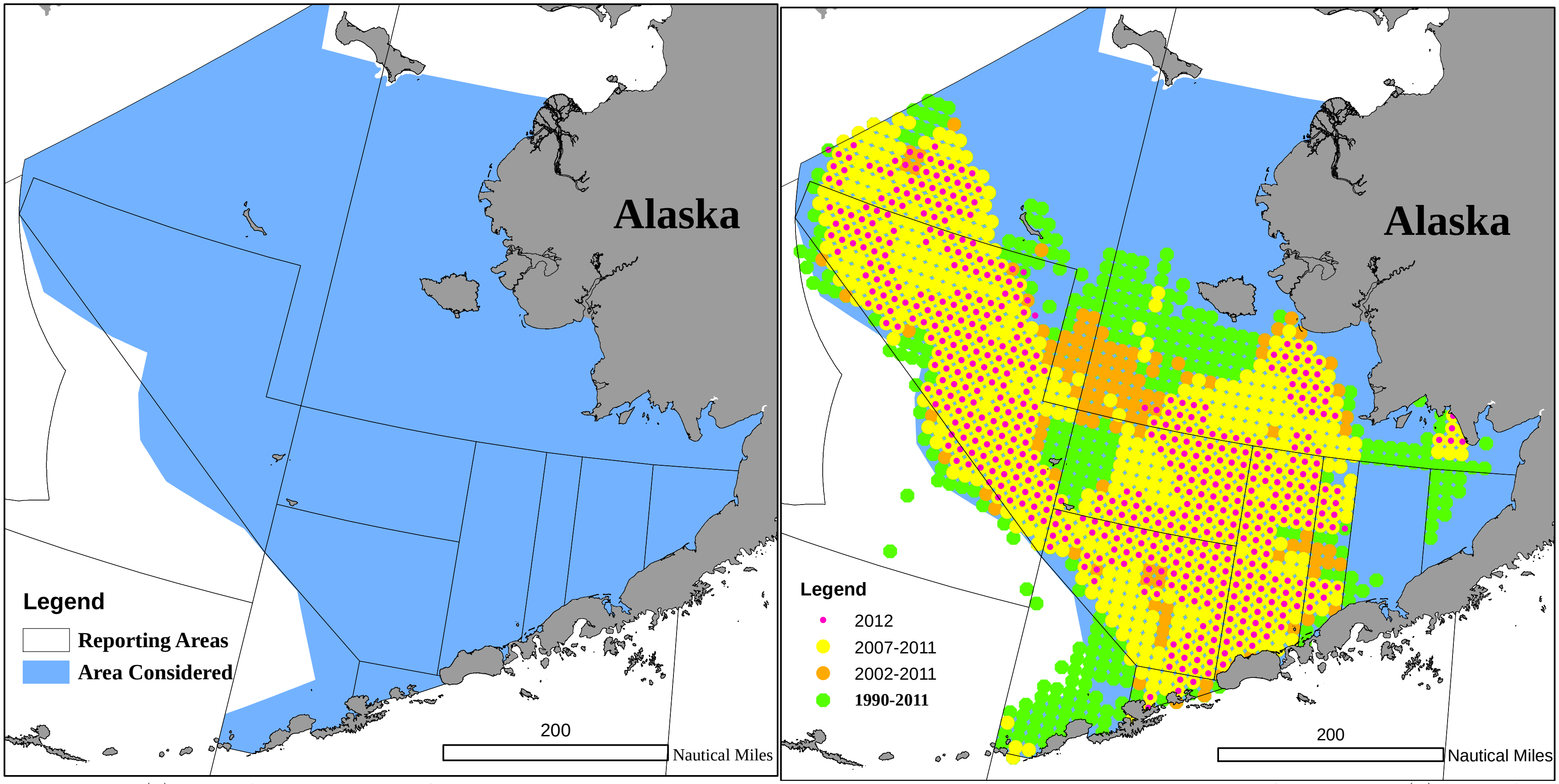

Figure 43: (a) Map of Eastern Bering Sea area considered when estimating percent area potentially disturbed by trawl fishing gear. (b) Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than 3 vessels are not shown

Status and Trends: The maximum total area of seafloor in the Eastern Bering Sea potentially disturbed by trawls varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed remained relatively stable in the 2000s with a slight increase in the 2007-2008. The percent of total area disturbed varied between 10% and 15% in the 1990s and between 9% and 11% in the 2000s, however due to trawls overlapping the same area the more realistic area disturbed was less than 10% from the mid 1990s on. Reduction in hours fished in the 2000s indicates greater fishing efficiency.

Factors Causing Trends: Trends in seafloor area disturbed can be affected by numerous variables, such as individual fishery movements, fish abundance and distribution, management actions (e.g., closed areas), changes in the structure of the fisheries due to rationalization, increased fishing skills (e.g., increased ability to find fish), and changes in vessel horsepower and fishing gear.

During 1993-1999, fishing effort was more concentrated in the southern area compared to 1990-1992 and 2000-2008, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-1998 relative to other years (Figure 44).

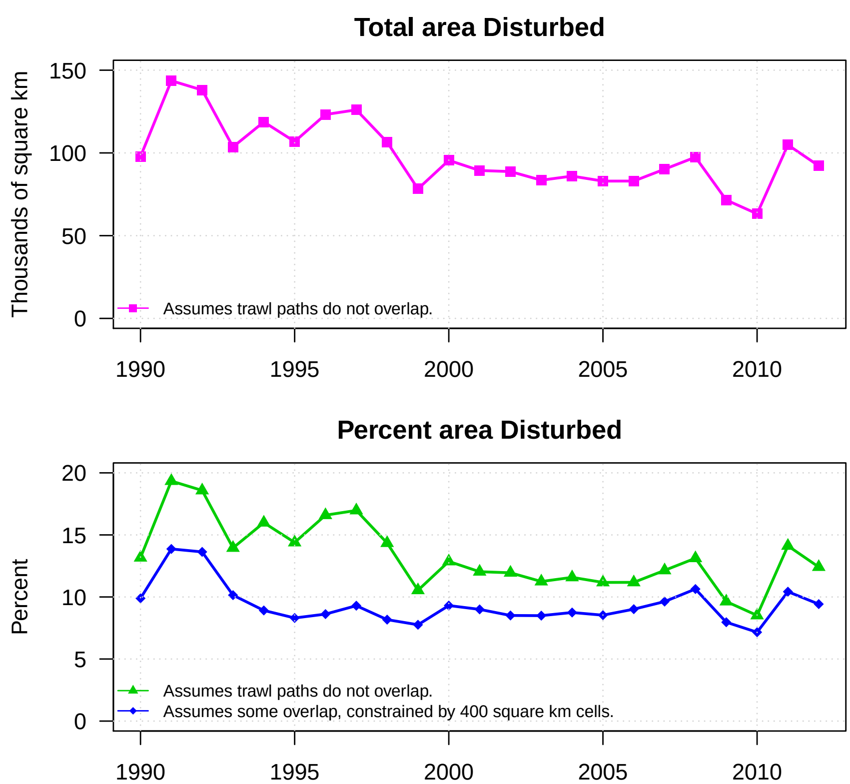

Figure 44: Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The green line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of area disturbed. The blue line represents the percent area disturbed with spatial overlap of trawl hauls within 400 km^2 cells, thereby, limiting the disturbance of trawls recorded in a cell to 400 km^2.

As of 1999 only pelagic trawls can be used in the Bering Sea pollock fisheries. To check to see if this affected the trends the graph was recalculated making no distinction between gears. The result showed no change to the trend. Short-wiring was only identified in the database from 1995 onward, however short-wiring accounts for only 2% of the total hauls and does not explain the early 1990 trends.

Implications: Habitat damage varies with the physical and biological characteristics of the areas fished, recovery rates of HAPC biota in the areas fished, and management changes that result in spatial changes in fishing effort.

Observed Hook and Line (Longline) Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed longline sets) is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available `http://alaskafisheries.noaa.gov/sustainablefisheries/observers/`.

This fishery is prosecuted with anchored lines, onto which baited hooks are attached. Gear components which may interact with benthic habitat include the anchors, groundline, gangions, and hooks. The fishery is prosecuted with both catcher and catcher-processor vessels.

Status and trends: Effort in the longline fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 45.

Bering Sea. For the period 2003-2012, there were a total of 133,338 observed longline sets in the Bering Sea fisheries. Spatial patterns of fishing effort were summarized on a 10 km^2 grid (Figure **??**). During 2012, the amount of observed longline effort was 14,237 sets, which represents an increase over 2011 and is slightly above the 10-year average for the fishery. Areas of high fishing effort are to the north and west of Unimak Island, the shelf edge represented by the boundary of report area 521, and to the south and west of St. George and St. Paul Islands. This fishery occurs mainly for Pacific cod, Greenland turbot, and sablefish. In 2012, fishing effort was anomalously high to the north of Unimak Island, with other areas to the west of St. George and north of Zhemchug Canyon also showing small localized increases (Figure 47).

Aleutian Islands. For the period 2003-2012 there were 16,076 observed hook and line sets in the Aleutian Islands. During 2012, the amount of observed longline effort was 1,169 sets, which is significantly below the 10-year average an increase over 2011. The spatial pattern of this effort was

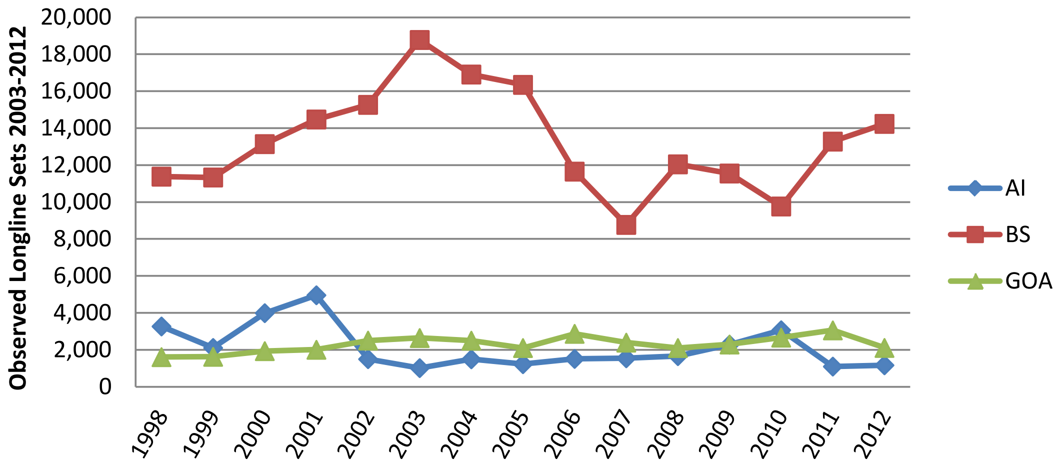

Figure 45: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of longline sets, 1990-2012.

dispersed over a wide area. Patterns of high fishing effort were dispersed along the shelf edge (Figure 48). This fishery occurs mainly on Pacific cod, Greenland turbot, and sablefish. The catcher vessel longline fishery occurs over mud bottoms. In the summer, the fish are found in shallow (150-250 ft) waters, but are deeper (300-800 ft) in the winter. Catcher-processors fish over more rocky bottoms in the Aleutian Islands. The sablefish/Greenland turbot fishery occurs over silt, mud, and gravel bottom at depths of 150 to 600 fm. In 2012, fishing effort anomaly showed no specific patterns, with a few small increases near Atka and Kiska (Figure 49).

Gulf of Alaska. For the period 2003-2012 there were 24,754 observed hook and line sets in the Gulf of Alaska. During 2012, the amount of observed longline effort was 2,109 sets, which is below the 10-year average. Patterns of high fishing effort were dispersed along the shelf in all management areas (Figure 50). The predominant hook and line fisheries in the Gulf of Alaska are composed of sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery; dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. The demersal shelf rockfish fishery occurs over bedrock and rocky bottoms at depths of 75 m to >200 m. The sablefish longline fishery occurs over mud bottoms at depths of 400 to ¿1000 m. This fishery is often a mixed halibut/sablefish fishery, with shortraker, rougheye, and thornyhead rockfish also taken. Sablefish has been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency. The cod longline fishery generally occurs in the western and central Gulf of Alaska, opening on January 1st and lasting until early March. Halibut prohibited species catch sometimes curtails the fishery. The cod fishery occurs over gravel, cobble, mud, sand, and rocky bottom, in depths of 25 fathoms to 140 fathoms. In 2012, fishing effort anomalies were varied throughout the region, with higher than average fishing occurring near the Shumagin Islands west in Area 610 and between Sitkinak and Barnabas in Area 630 (Figure 51).

Factors influencing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures) as well as changes in markets and bycatch rates of non-target and prohibited species. Hook and line effort in both the Bering Sea and Aleutian Islands occurs mainly for Pacific cod, Greenland turbot, halibut and sablefish. The predominant hook and line fisheries in the Gulf of Alaska are composed of halibut, sablefish and Pacific cod. In southeast Alaska, there is a demersal rockfish fishery dominant species include yelloweye rockfish (90%), with lesser catches of quillback rockfish. Sablefish and halibut have been an IFQ fishery since 1995, which has reduced the number of vessels, crowding, gear conflicts and gear loss, and increased efficiency.

Implications: The effects of changes in fishing effort on habitat are largely unknown. It is possible that increases in hook and line and pot fisheries could result in increased habitat loss/degradation due to fishing gear effects on benthic habitat and other species have the opposite effect. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

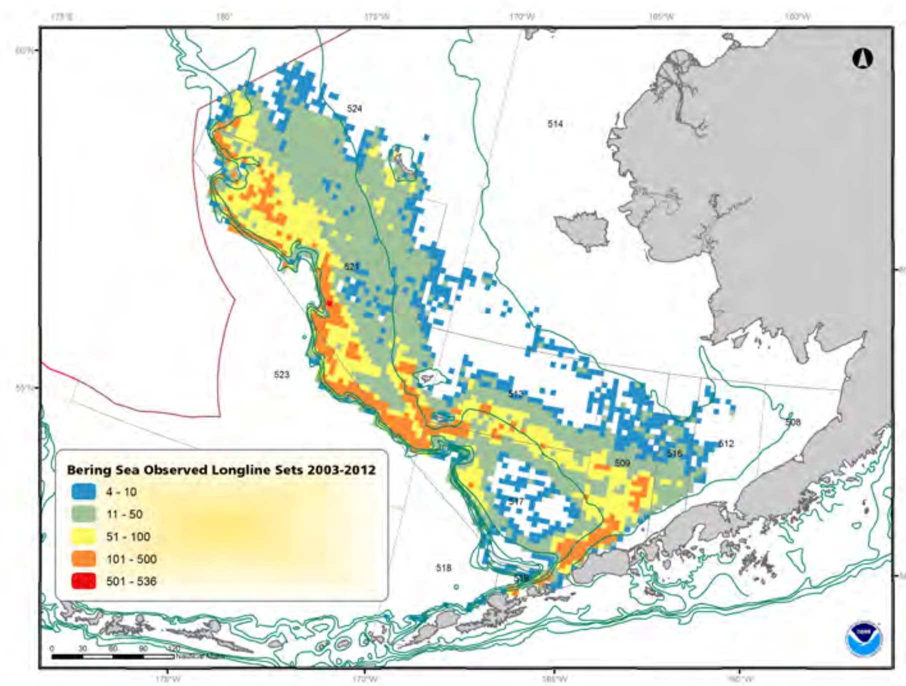

Figure 46: Observed longline effort (sets) in the Bering Sea 2003-2012.

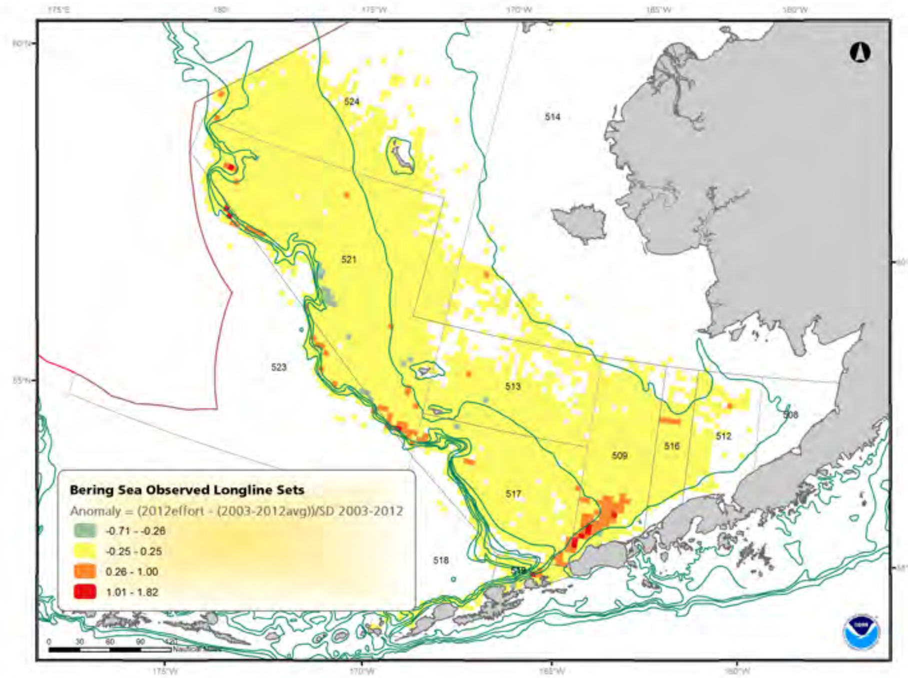

Figure 47: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

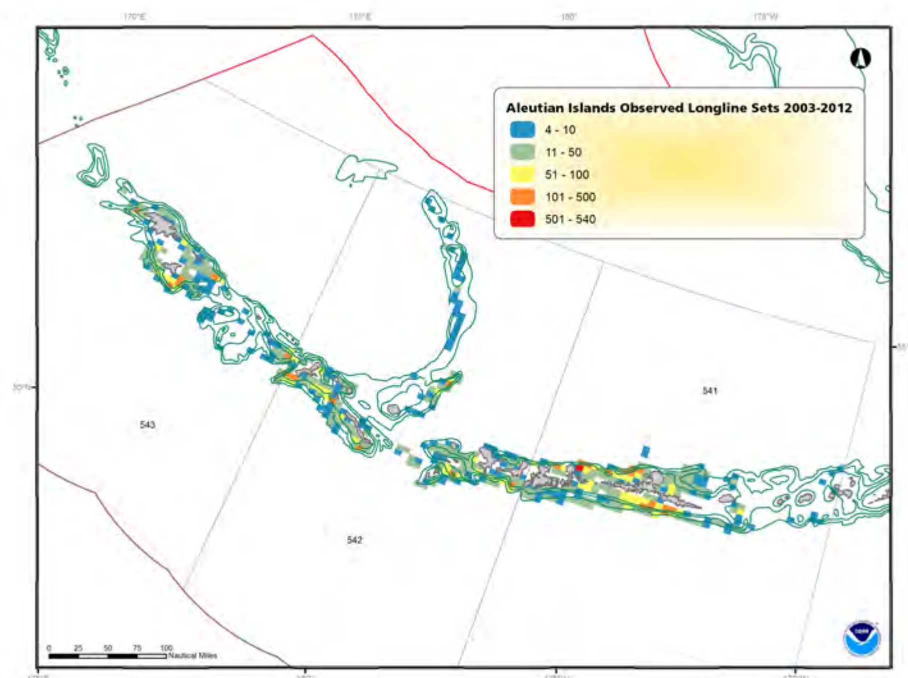

Figure 48: Observed longline effort (sets) in the Aleutian Islands, 2003-2012.

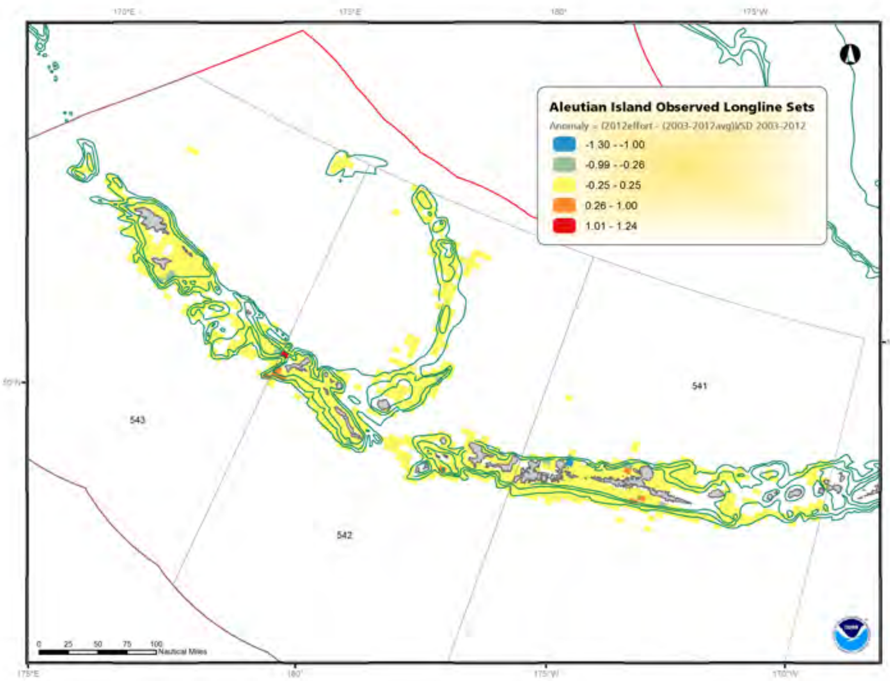

Figure 49: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

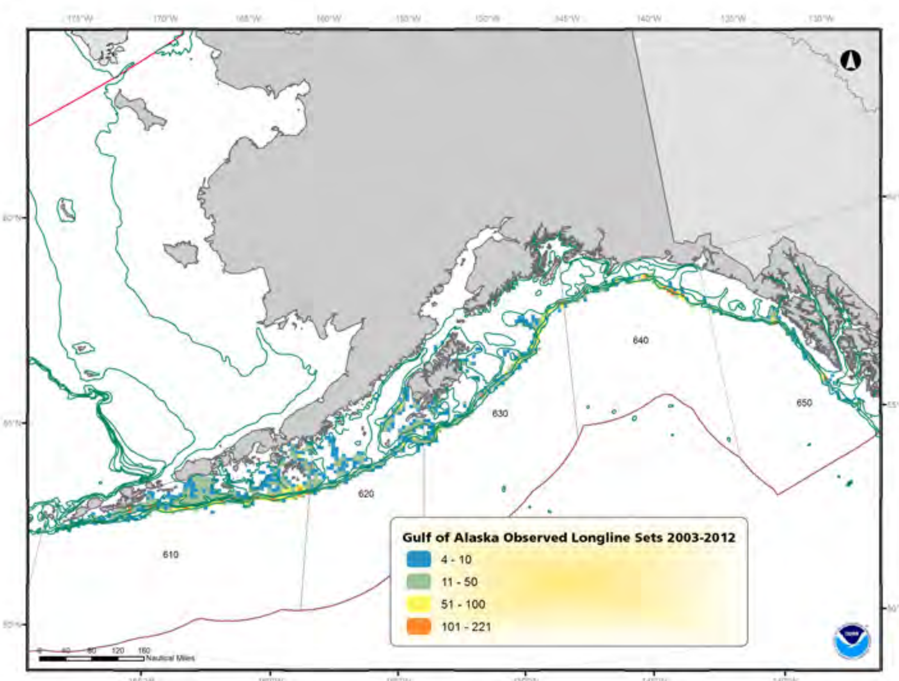

Figure 50: Observed longline effort (sets) in the Gulf of Alaska, 2003-2012.

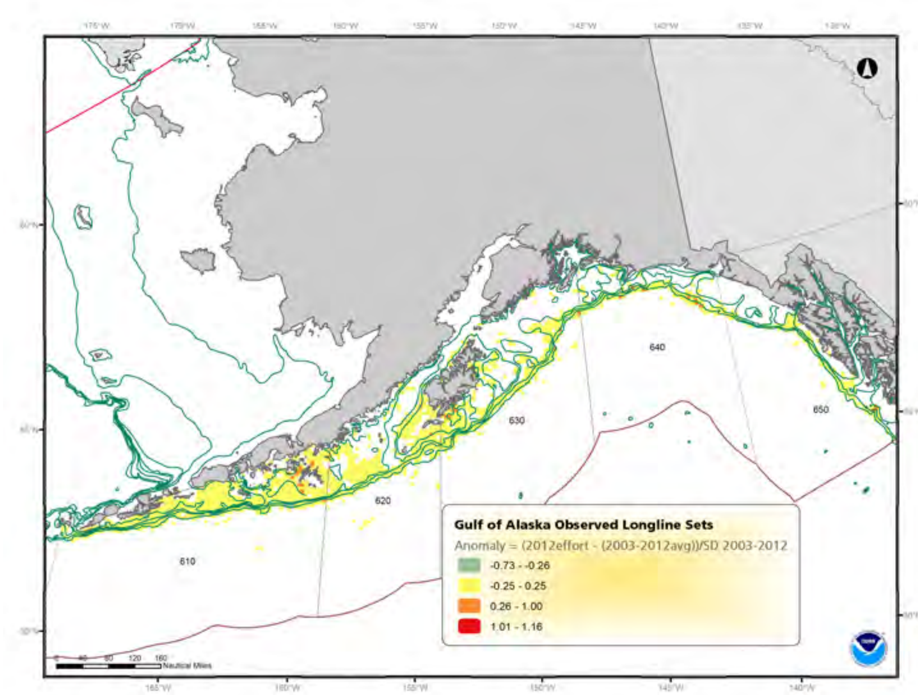

Figure 51: Observed longline fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Observed Groundfish Bottom Trawl Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed tows) is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available http://alaskafisheries.noaa.gov/sustainablefisheries/observers/. This fishery is prosecuted with towed non-pelagic trawls. Gear components which may interact with benthic habitat include the trawl doors, sweeps, and footropes. The fishery is prosecuted with both catcher and catcher-processor vessels.

Status and trends: In general, bottom trawl effort in the Bering Sea, Aleutian Islands, and Gulf of Alaska has been relative steady or slightly declining since 1998 (Figure 52). The magnitude of the Bering Sea trawl fisheries is more than four as large (in terms of effort) as the Aleutian Islands and Gulf of Alaska fisheries combined. Fluctuations in fishing effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent cod and pollock. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries.

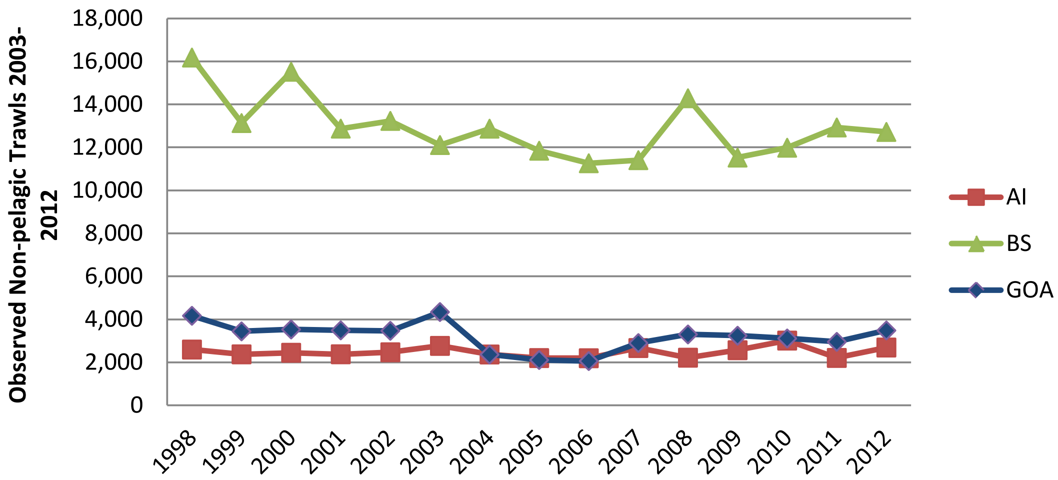

Figure 52: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of bottom trawl tows, 1990-2012.

Bering Sea. For the period 2003-2012, there were a total of 122,948 observed bottom trawl tows in the Bering Sea fisheries. During 2012, observed bottom trawl effort consisted of 12,720 tows, which was slightly above average compared to the past 10 years. Spatial patterns of fishing effort are summarized on a 10 km2 grid (Figure 53). Areas of high fishing effort are north of Unimak Pass/Island as well the southeast portion of Area 51, western portions of Area 509, and to the west of St. Paul Island in Area 521. Additional small areas of concentration exist near Cape Constantine and off of Kuskokwim Bay. The primary catch in these areas was Pacific cod and yellowfin sole. In 2012, fishing effort was higher than average north of Unimak Island and the Alaska Peninsula in the southern portion of area 509, as well as to the north of Area 513 (Figure 54).

Aleutian Islands. For the period 2003-2012 there were 24,892 observed bottom trawl tows in the Aleutian Islands. During 2012, the amount of observed bottom trawl effort was 2,691 tows, which was about average for the 10-year period. It represents an increase over 2011. Patterns of high fishing effort are Aleutian Islands, Bering Sea, and Gulf of Alaska dispersed throughout the Aleutian Islands (Figure 55). The primary catches in these areas were Pacific cod and Atka mackerel. Catch of Pacific ocean perch by bottom trawls was also high in earlier years. In 2012, areas of anomalous fishing effort were minimal but scattered throughout the region, with higher than average observed effort south of Sequam Island (Figure 56). Some areas now have lower patterns of fishing effort which could be due to the implementation of new management measures, including SSL measures in areas 542 and 543 in 2011. In 2006, the Aleutian Islands Habitat Conservation Area (AIHCA) closed approximately 279,114 nm2 to bottom trawl fishing in the three AI management areas.

Gulf of Alaska. For the period 2003-2012 there were 29,869 observed bottom trawl tows in the Gulf of Alaska. The spatial pattern of this effort was much more dispersed than in the Bering Sea region. During 2012, the amount of trawl effort was 3,484 tows, which was an increase over

2011 and also above the average for the 10-year period. For 2012, fishing effort did not display any distinct patterns of anomaly; rather, small areas of small increases were evident over arease 620 and 630. Patterns of high fishing effort were dispersed along the shelf edge with high pockets of effort near Chirkoff, Cape Barnabus, Cape Chiniak and Marmot Flats (Figure 57). Primary catches in these areas were Pacific cod, flatfish and rockfish. A larger portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 30% observer coverage, indicating that the actual amount of trawl effort would be much higher since a large portion is unobserved. In 2011, areas of higher and lower than average fishing effort were scattered throughout the Central and Western Gulf (Figure 58).

Factors influencing observed trends: Spatial changes in fisheries effort may in part be affected by many factors, including fishing closure areas (i.e., habitat closures, Steller sea lion protection measures) as well as changes in markets, environmental conditions, and/or increased bycatch rates of non-target species. Some of the reduction in bottom trawl effort in the Bering Sea after 1997 can be attributed to changes in the structure of the groundfish fisheries due to rationalization. As of 1999, only pelagic trawls can be used in the Bering Sea pollock fisheries. Fluctuations in bottom trawl effort track well with overall landings of primary bottom trawl target species, such as flatfish and to a lesser extent cod and pollock.

Implications: Fishing effort is an indicator of damage to or removal of both living and nonliving bottom substrates, damage to small epifauna and infauna, and reduction in benthic biodiversity by mobile (trawl) or fixed (longline, pot) gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed in the wake of the tow, or by reducing the suitability of habitat used by some species. Trends in fishing effort will reflect changes due to temporal, geographic, and market variability of fisheries as well as management actions. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing

The effects of changes in fishing effort on habitat are largely unknown. It is possible that the reduction in bottom trawl effort in all three ecosystems could result in decreased habitat loss/degradation due to fishing gear effects on benthic habitat and other species. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`). Also, much of the fleet in the Bering Sea has adopted the use of sweep modifications on their nets.

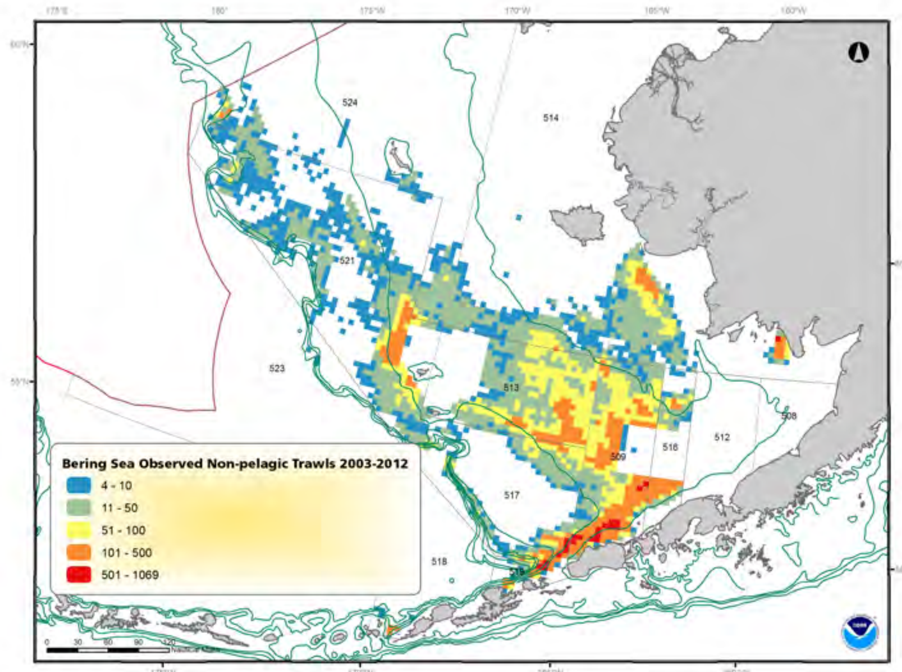

Figure 53: Spatial location and density of observed bottom trawling in the Bering Sea 1998-2012.

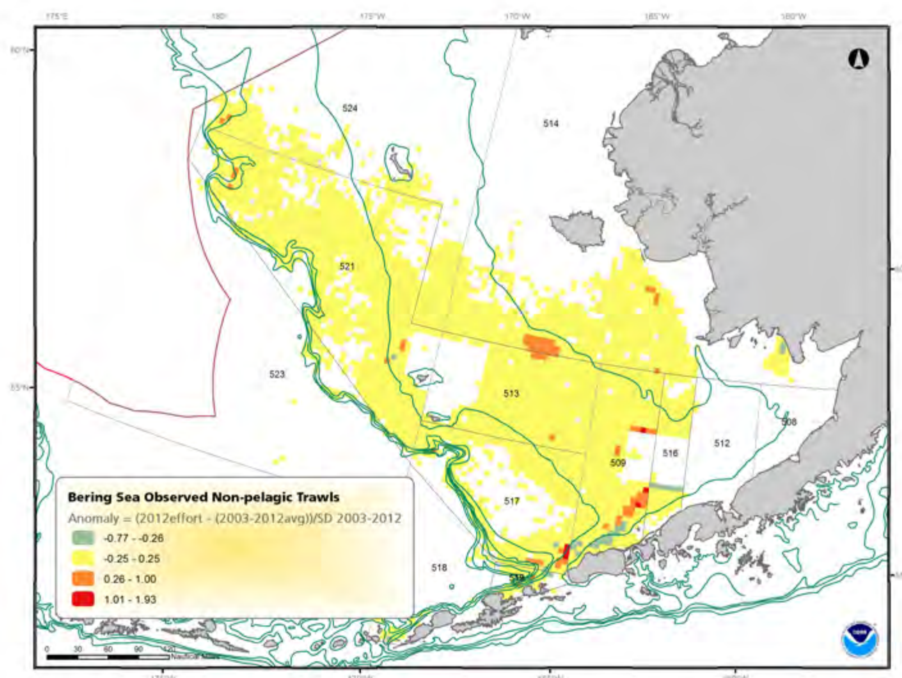

Figure 54: Observed bottom trawl fishing effort in 2012 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

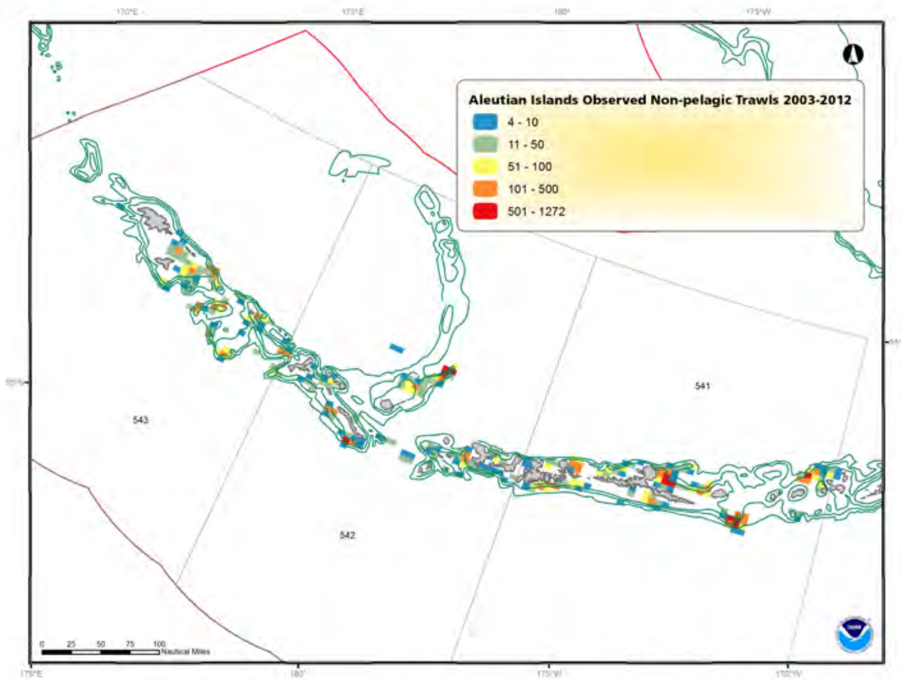

Figure 55: Spatial location and density of observed bottom trawl effort in the Aleutian Islands, 1998-2012.

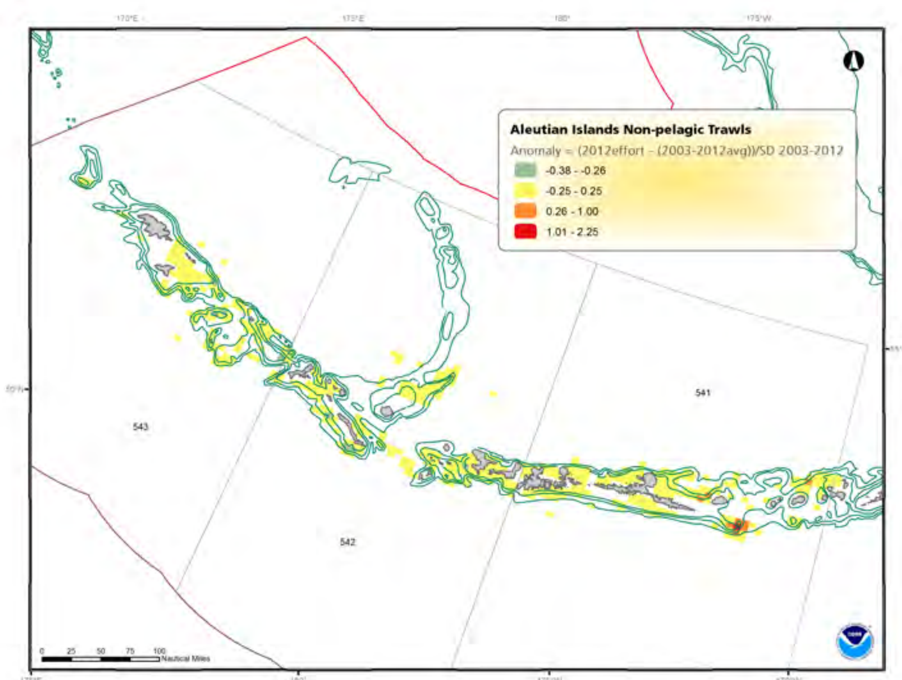

Figure 56: Observed bottom trawl fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

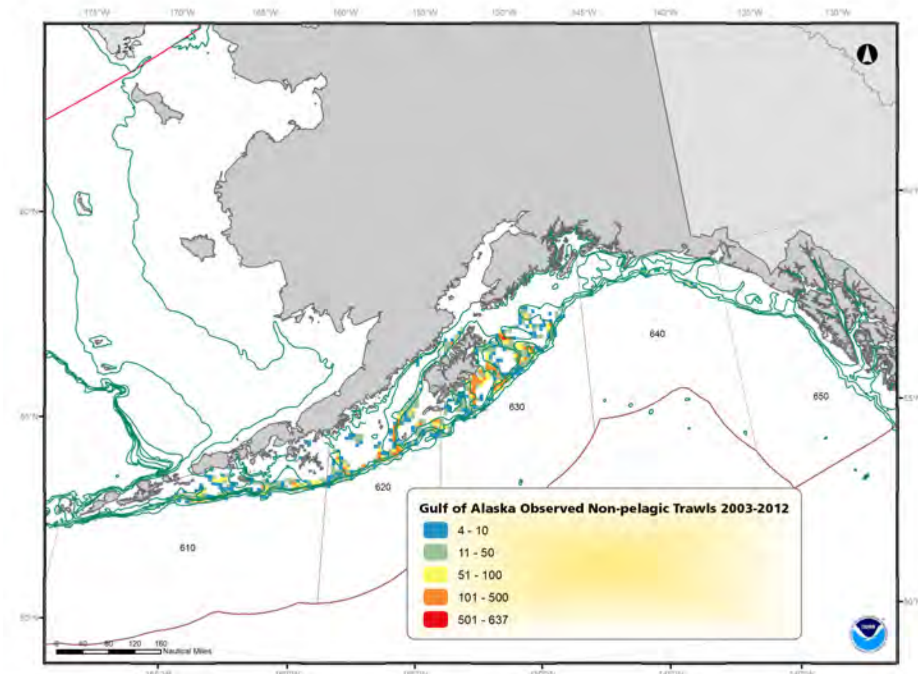

Figure 57: Spatial location and density of observed bottom trawl effort in the Gulf of Alaska, 1998-2012.

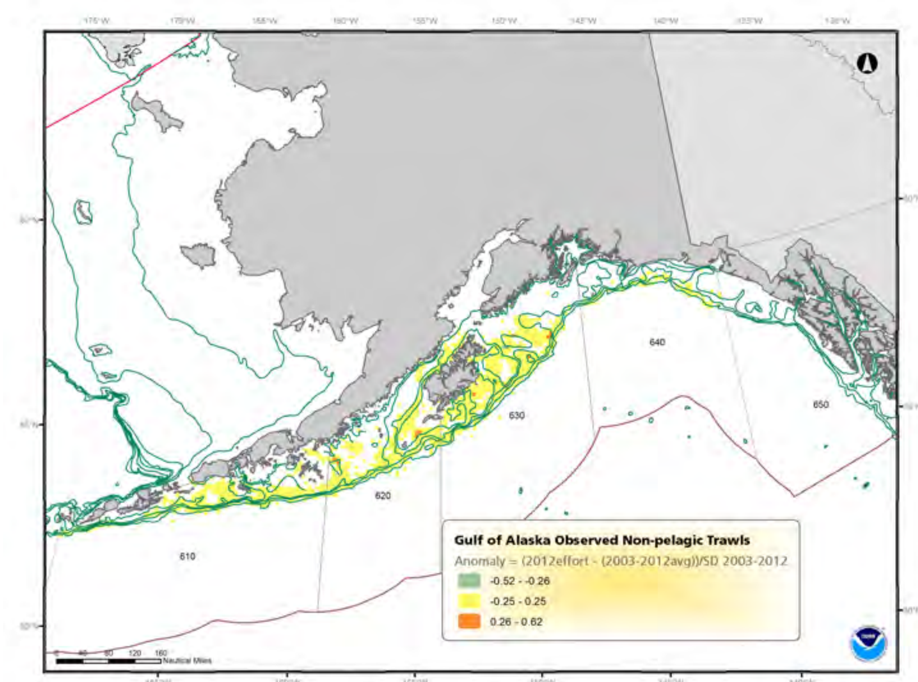

Figure 58: Observed bottom trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Observed Groundfish Pelagic Trawl Fishing Effort in the Gulf of Alaska, Bering Sea and Aleutian Islands

Contributed by John Olson, Habitat Conservation Division, Alaska Regional Office, National Marine Fisheries Service, NOAA
Contact: john.v.olson@noaa.gov
Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed tows) is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available http://alaskafisheries.noaa.gov/sustainablefisheries/observers/.

This fishery is prosecuted with towed pelagic trawls. Gear components which may interact with benthic habitat include the trawl sweeps and footrope. The fishery is prosecuted with both catcher and catcher-processor vessels.

Status and trends: Effort in the pelagic trawl fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 59. The magnitude of the Bering Sea trawl fisheries effort is four times larger than effort in both the Gulf of Alaska and Aleutian Islands (which has had no significant effort since 1998 and zero effort in 2011 and 2012) combined. While this fishery is much larger than in the other two regions, smaller vessels that only require 30% observer coverage occur in larger proportions in the GOA resulting in less documented fishing effort. Figures **??** show the spatial patterns and intensity of pelagic trawl effort by region, based on observed data.

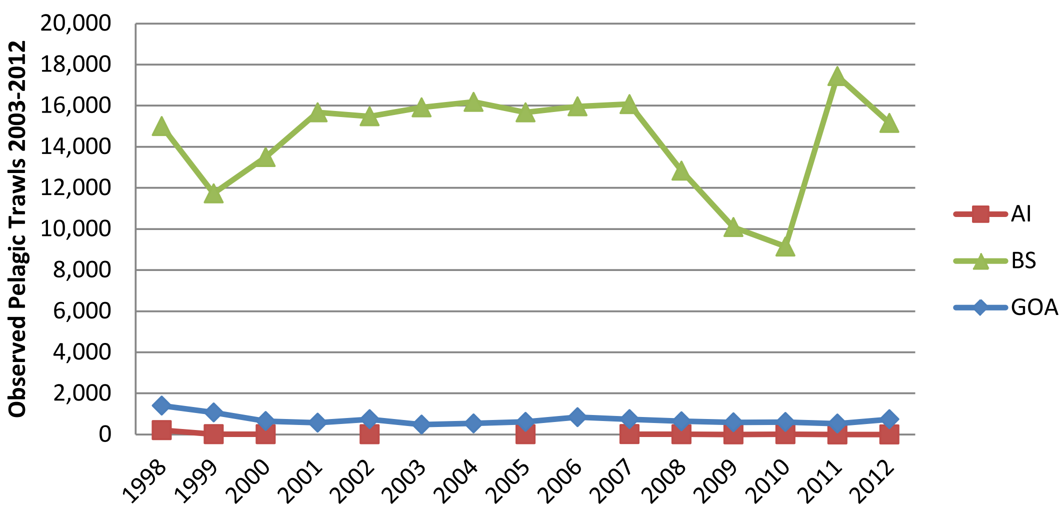

Figure 59: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pelagic trawl tows, 1990-2012.

Bering Sea. For the period 2003-2012 there were 144,486 observed pelagic trawl tows in the Bering

Sea (Figure **??**). There were 15,159 observed tows in 2012, which is just slightly higher than the 10-year average and a decrease from 2011. Areas of high fishing effort are north of Unimak Island and between the 100 and 200m contours in management areas 509, 513, 517, 519, and 521. Fishing was also focused near the Pribilof Islands, and northwest between the 100-200 meter contours. The predominant species harvested within the eastern Bering Sea is walleye pollock. Pollock occur on the sea bottom, the midwater and up to the surface. Most catch of pollock is taken at 50-300m. In 2012, fishing effort was slightly higher than normal north of Unimak Island, an area of normally high fishing effort (Figure 61). Increased fishing effort also occurred to the southeast of St George Island. Some changes in fleet movement may be attributed to the AFA fishing coop structure and voluntary rolling hotspot closures to reduce the incidental take of Chinook and "Other Salmon" bycatch; whereas, other changes in fishing effort might be attributed to changes in pollock distribution.

Aleutian Islands. For the period 2003-2012 there were a total of 53 observed pelagic trawl tows in the Aleutian Islands. In 2001, 2003, 2004, 2006, 2011 and 2012 there were no observed pelagic trawl tows. Patterns of high fishing effort, mainly before 1999, were historically dispersed along the shelf edge. As there have been no tows were recorded in the Aleutian Islands in 2012, maps of effort and anomaly are not included.

Gulf of Alaska. The primary target of the GOA pelagic trawl fishery is pollock (Figure **??**). The fleet is comprised of trawl catcher vessels that deliver their catch onshore for processing. For the period 2003-2012 there were 6,326 observed pelagic trawl tows in the Gulf of Alaska. The spatial pattern of this effort centers around Kodiak, specifically Chiniak Gully, Marmot Bay and Shelikof Strait, with limited fishing on the shelf break to the east and west. During 2012, the amount of trawl effort was 742 tows, which was above average for the 10-year period. A large portion of the trawl fleet in Kodiak is comprised of smaller catcher vessels that require 3% observer coverage, indicating that the actual amount of trawl effort is likely much higher since a large portion is unobserved. The catch anomaly for 2012 was variable, with the highest anomaly centered in Shelikof Strait Figure **??**).

Factors causing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures), changes in markets, changes in environmental conditions, and increased bycatch rates of non-target species. The Bering Sea pollock fishery is the largest volume U.S. Fishery, and most pollock is harvested with pelagic trawl nets. Effort in the Bering Sea remained at a relatively stable through 2007. Effort (and TAC) declined through 2010, at which point pelagic trawl effort again increased near the long-term average in 2011 and 2012. Some of the consistency of effort can be attributed to changes in the structure of the groundfish fisheries due to rationalization. Effort in both the GOA and AI has trended downward in the last decade, in part due to restricted fishing from Steller sea lion protection measures.

In 1990, concerns about bycatch and seafloor habitats affected by the large Bering Sea pelagic trawl fishery led the North Pacific Fishery Management Council to apportion 88 percent of TAC to the pelagic trawl fishery and 12 percent to the non-pelagic trawl fishery (North Pacific Fishery Management Council, 1999). For practical purposes, non-pelagic trawl gear is defined as trawl gear that results in the vessel having 20 or more crabs (*Chionecetes bairdi*, *C. opilio*, and *Paralithodes camstschaticus*) larger than 1.5 inches carapace width on board at any time. Crabs were chosen as the standard because they live only on the seabed and they provide proof that the trawl has been in contact with the bottom.

Pollock fishermen formed fish harvesting cooperatives to "rationalize" fishing activities, including resolving problems of overcapacity, promoting conservation and enhancing utilization of fishery resources. Under a co-op arrangement, fewer vessels are fishing and daily catch rates by participating vessels are significantly reduced since the "race for fish" ended in 1999. Bering Sea chinook and chum bycatch led to NPFMC action limiting the total bycatch of these species. More information is available at `http://www.fakr.noaa.gov/npfmc/bycatch-controls/BSChinookBycatch.html`.

Management measurements have affected the pelagic trawl fishing effort in the Aleutian Islands. In recent years pollock fishing in the Aleutian Islands has been restricted by the Stellar Sea Lion Closures. The western distinct population segment of Steller sea lions occurs in the Aleutian Islands subarea and is listed as endangered under the Endangered Species Act (ESA). Critical habitat has been designated for this area, including waters within 20 nautical miles (nm) of haulouts and rookeries. Pollock is a principal prey species of Steller sea lions.

Aleutian Islands pollock had been harvested primarily in Steller sea lion critical habitat in the past until the Aleutian Islands subarea was closed to pollock fishing in 1999. In 2003, the Aleutian Islands subarea was opened to pollock fishing outside of critical habitat under regulations implementing the current Steller sea lion protection measures. Part of the 2004 Consolidated Appropriations Act required that the directed fishing allowance of pollock in the Aleutian Islands subarea be allocated to the Aleut Corporation. The Aleut Corporation harvested only about 1 percent of its initial 2005 pollock allocation due, in part, to difficulty in finding pollock. To harvest the fish, the Aleut Corporation is allowed to contract only with vessels under 60 feet length overall or vessels listed under the American Fisheries Act. The smaller vessels do not require observer coverage.

Implications: Fishing effort is an indicator of damage to or removal of both living and nonliving bottom substrates, damage to small epifauna and infauna, and reduction in benthic biodiversity by mobile (trawl) or fixed (longline, pot) gear. Intensive fishing in an area can result in a change in species diversity by attracting opportunistic fish species which feed on animals that have been disturbed in the wake of the tow, or by reducing the suitability of habitat used by some species. Trends in fishing effort will reflect changes due to temporal, geographic, and market variability of fisheries as well as management actions. These changes in effort can be observed by examining effort for the current year relative to the average effort in prior years of fishing

The effects of changes in fishing effort on habitat are largely unknown. It is possible that the reduction in bottom trawl effort in all three ecosystems could result in decreased habitat loss/degradation due to fishing gear effects on benthic habitat and other species. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

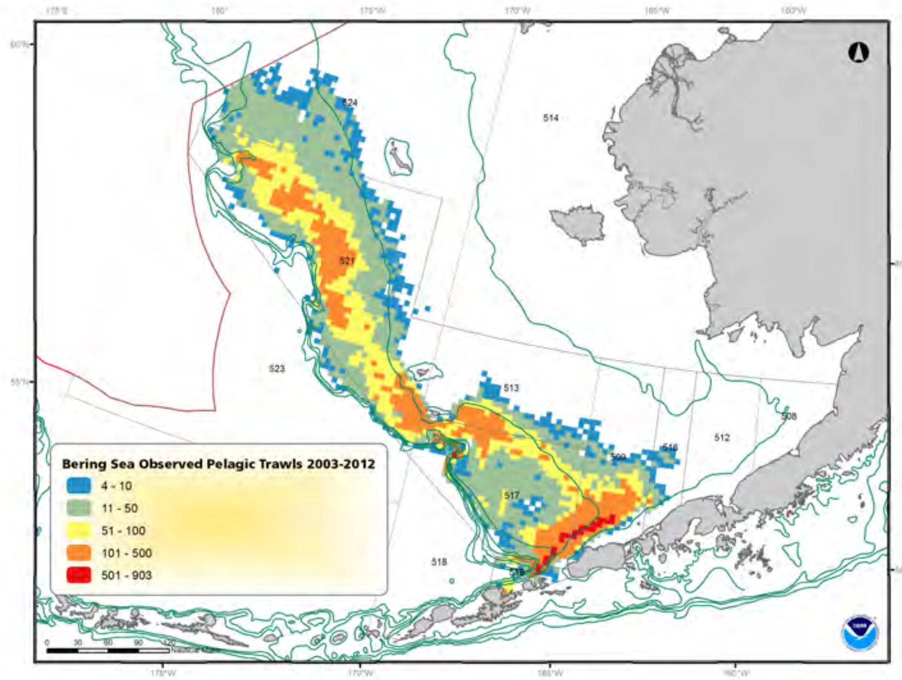

Figure 60: Spatial location and density of observed pelagic trawling in the Bering Sea 1998-2012.

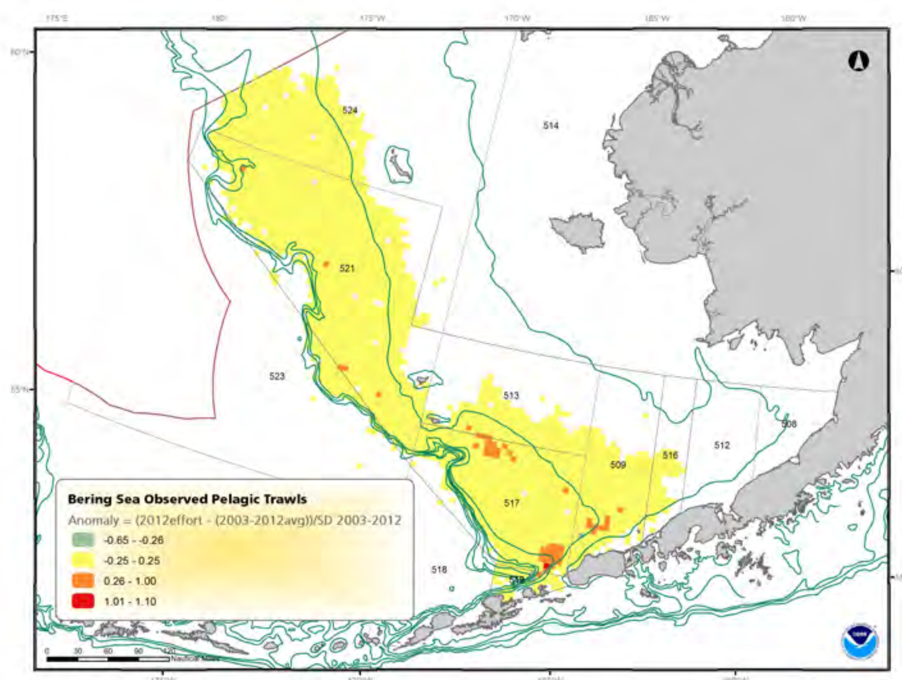

Figure 61: Observed pelagic trawl fishing effort in 2012 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

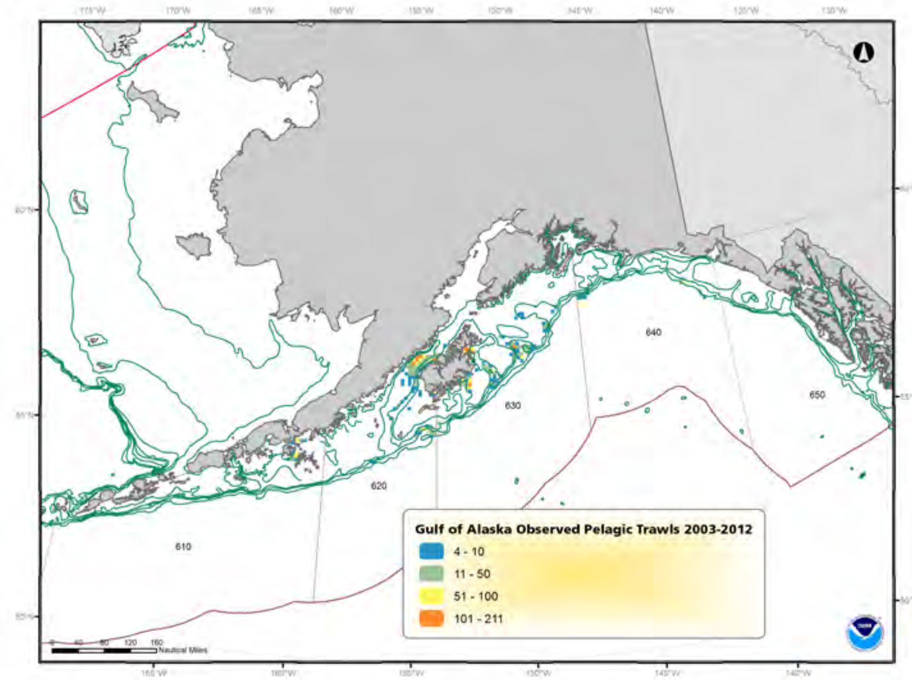

Figure 62: Spatial location and density of observed pelagic trawl effort in the Gulf of Alaska, 1998-2012.

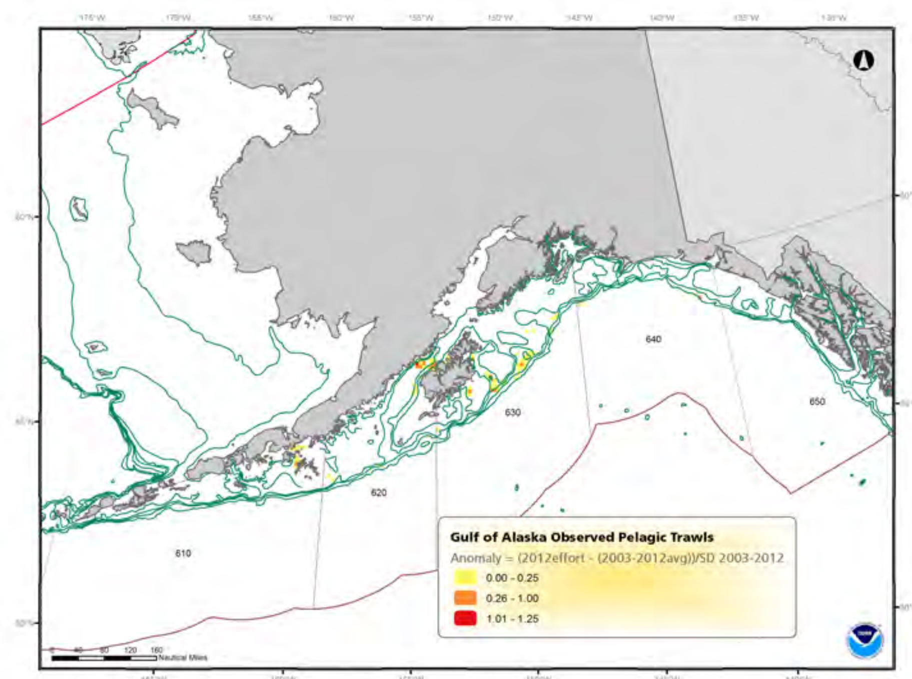

Figure 63: Observed pelagic trawl fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Observed Pot Fishing Effort in the Gulf of Alaska, Bering Sea, and Aleutian Islands

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Last updated: August 2013

Description of index: Observed fishing effort (as measured by observed pot lifts) is used as an indicator of total fishing effort. It should be noted, however, that many all fishing effort is not observed. Previously, catcher vessels under 60' were not observed and vessels between 60'-125 required 30% observer coverage. Starting in January 2013, a restructured observer system was implemented whereby all sectors of the groundfish fishery, including vessels less than 60' and the commercial halibut sector would be observed. NMFS now has the flexibility to decide when and where to deploy observers based on a scientifically defensible deployment plan. More information is available http://alaskafisheries.noaa.gov/sustainablefisheries/observers/. This fishery is prosecuted with set pots, which are generally converted from crab pots with triggers. Gear components which may interact with benthic habitat include the pot. The fishery is prosecuted with catcher vessels.

Status and trends: The observed pot fishing effort has increased in both the Bering Sea and Gulf of Alaska since 2010. Effort in the pot fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska is shown in Figure 64.

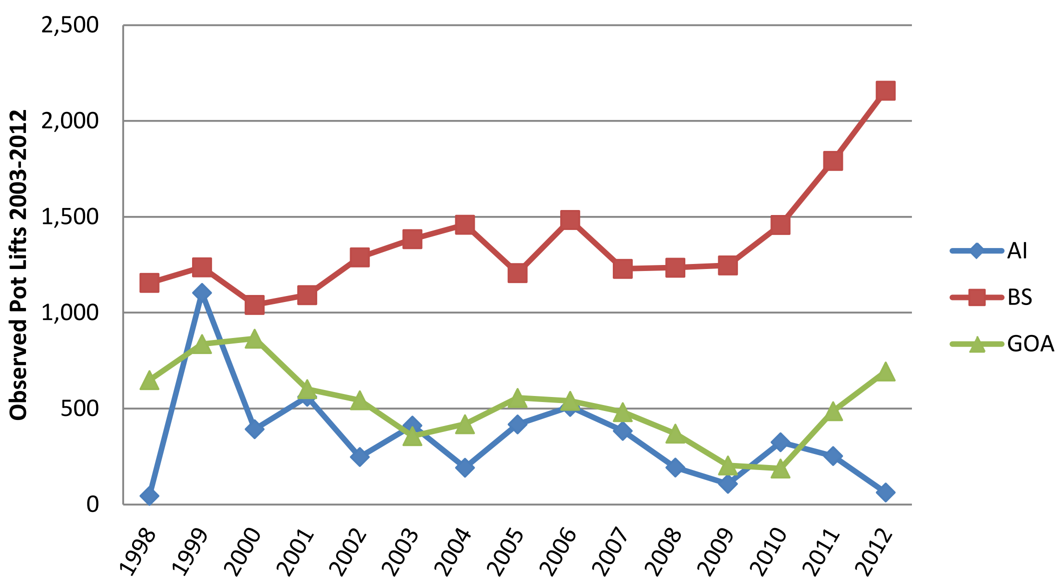

Figure 64: Gulf of Alaska, Bering Sea, and Aleutian Islands observed number of pot lifts, 1998-2012.

Bering Sea. For the period 2003-2012, there were a total of 14,653 observed pot lifts in the Bering Sea fisheries. During 2012, the amount of observed pot effort was 2,158 lifts, which was higher than the 10-year average of 1,465 and also an increase from 2011. Spatial patterns of fishing effort were summarized on a 10 km2 grid (Figure 65). Areas of high fishing effort are west of Unimak Island. This fishery occurs mainly for Pacific cod which form dense aggregations for spawning in the winter months. Effort anomalies occurred mainly to the west of Unimak Island (higher effort in 2011)(Figure 66). Spatial and temporal changes to the fishery may have occurred in the past 10 years due to current Steller Sea Lion regulations as well as changes in Pacific cod TAC.

Aleutian Islands. For the period 2003-2012 there were 2,857 observed pot lifts in the Aleutian Islands. During 2012, the amount of observed pot effort was 63 lifts, which represents a substantial decline from 2011 and is well below the 10-year average of 286. Fishing effort was dispersed along the shelf edge with high effort near Amlia and Seguam Islands (Figure 67). In 2012, the fishing anomaly throughout the region was minimal (Figure 68).

Gulf of Alaska. For the period 2003-2012 there were 4,298 observed pot lifts in the Gulf of Alaska. During 2012, the amount of observed pot effort was 694 lifts, which represents an increase from 2011 and is above the 10-year average of 430. Patterns of higher fishing effort were dispersed along the shelf to the east of Kodiak Island (Figure 69). Fishing effort in 2012 showed increases in areas 610 and 630, particularly near Shumagin Islands, Middle Cape, and the southern and eastern portions of Kodiak Island (Figure 70). Approximately 100 boats participate in this fishery. There is also a state-managed fishery in state waters. Vessels used in the inshore fishery are all catcher vessels of small (less than 60-foot LOA) and medium size (60- to 125-foot LOA). The offshore fishery includes some catcher-processors ranging from 90 to over 125 feet. The A season fishery begins on January 1st and concludes in early March. The B season fishery opens September 1 and can be expected to last 6 weeks or less. There is also a state-managed fishery in state waters.

Factors causing observed trends: Spatial changes in fisheries effort may in part be affected by fishing closure areas (i.e., Steller sea lion protection measures, crab and habitat closures) as well as changes in markets and increased bycatch rates of non-target species. The pot fishery occurs mainly for Pacific cod which form dense spawning aggregations in the winter months. In the Bering Sea, fluctuations in the pot cod fishery may be dependent on the duration and timing of crab fisheries. There is also a state-managed fishery in State waters.

Implications: The effects of changes in fishing effort on habitat are largely unknown. It is possible that the reduction in bottom trawl effort in all three ecosystems could result in decreased habitat loss/degradation due to fishing gear effects on benthic habitat and other species; whereas, increases in hook and line and pot fisheries could have the opposite effect. The footprint of habitat damage likely varies with gear (type, weight, towing speed, depth of penetration), the physical and biological characteristics of the areas fished, recovery rates of living substrates in the areas fished, and management changes that result in spatial redistribution of fishing effort (NMFS, 2007)(`http://www.nmfs.noaa.gov/pr/permits/eis/steller.htm`).

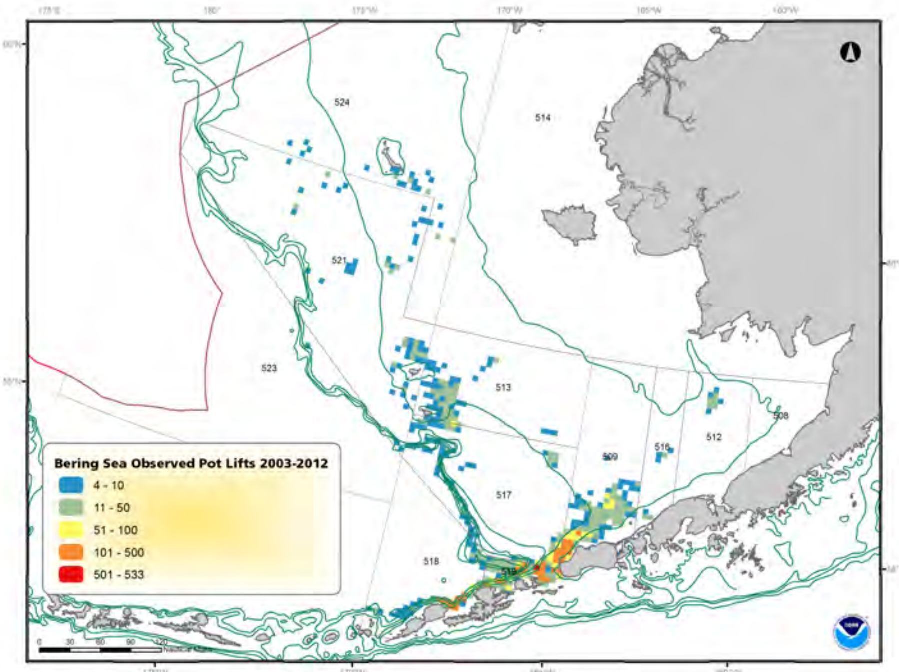

Figure 65: Spatial location and density of pot effort (observed number of pot lifts) in the Bering Sea 1998-2012.

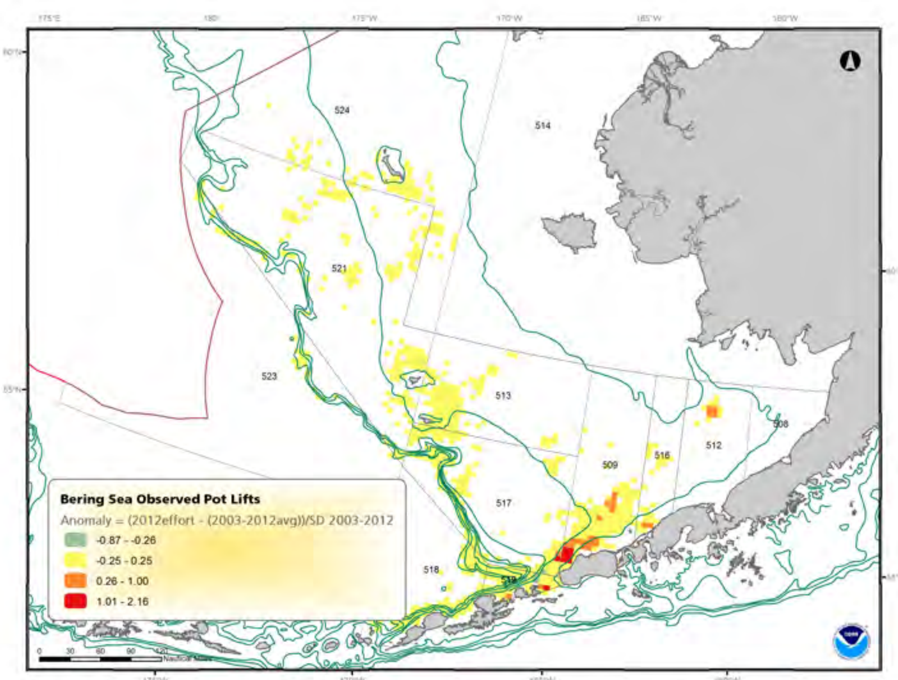

Figure 66: Observed pot fishing effort in 2012 relative to the 2003-2012 average in the Bering Sea. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

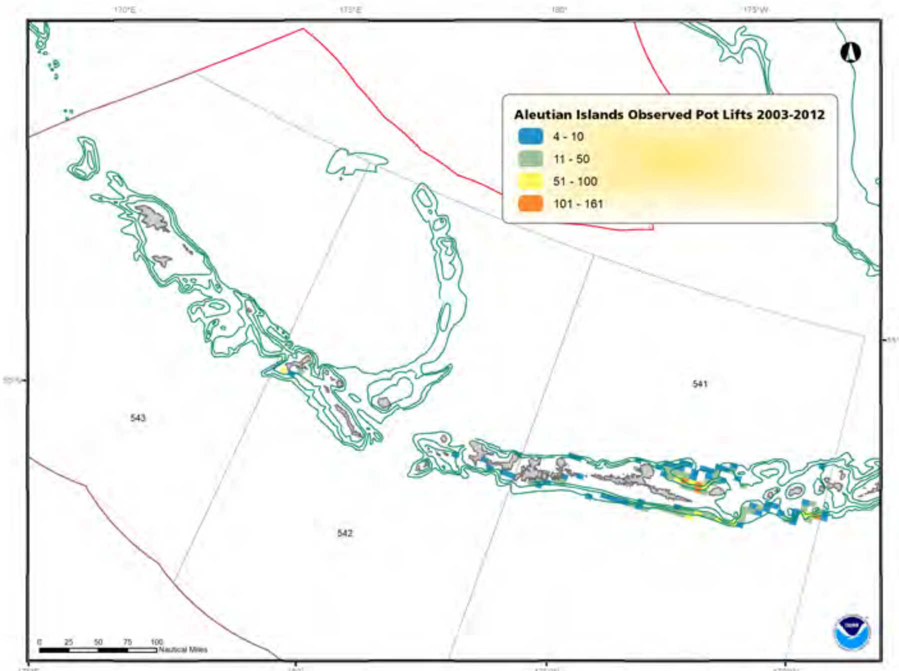

Figure 67: Spatial location and density of pot effort (observed number of pot lifts) in the Aleutian Islands, 1998-2012.

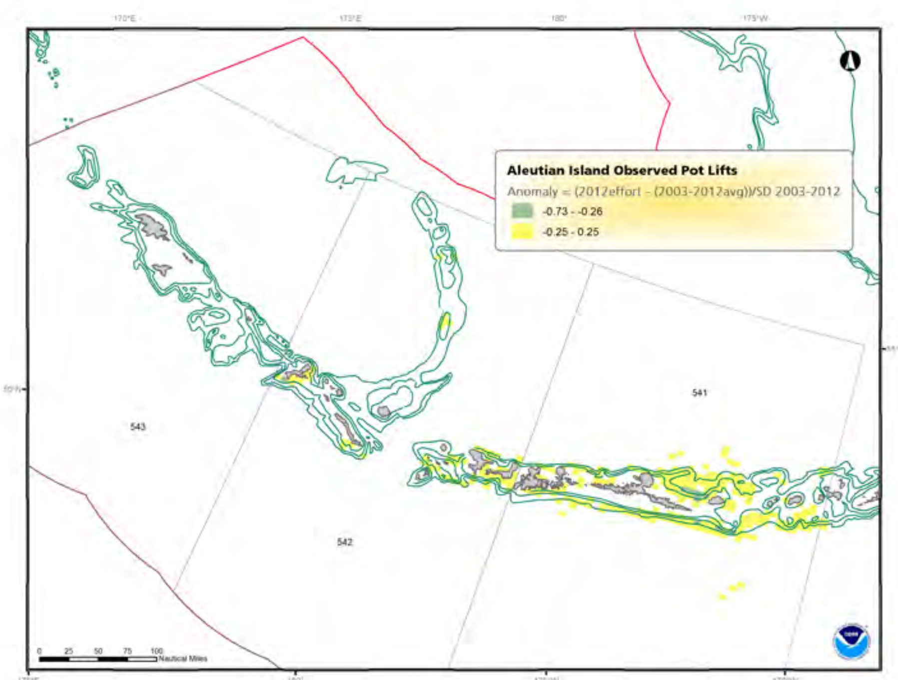

Figure 68: Observed pot fishing effort in 2012 relative to the 2003-2012 average in the Aleutian Islands. Anomalies calculated as (estimated effort for 2012 - average effort from 2003-2012)/stdev(effort from 2003-2012).

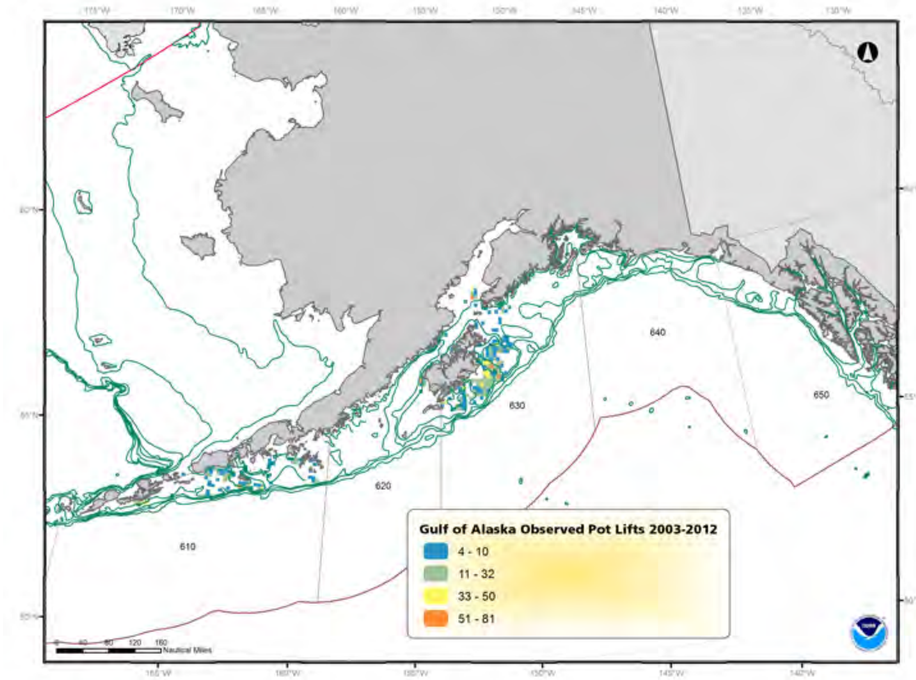

Figure 69: Spatial location and density of pot effort (observed number of pot lifts) in the Gulf of Alaska, 1998-2012.

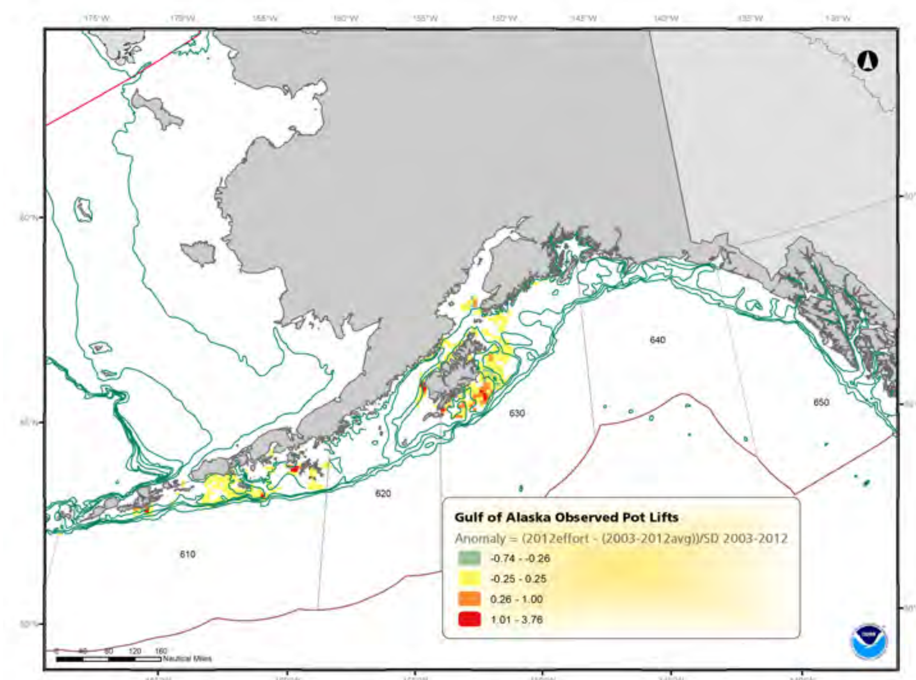

Figure 70: Observed pot fishing effort in 2011 relative to the 2003-2012 average in the Gulf of Alaska. Anomalies calculated as (observed effort for 2012 - average observed effort from 2003-2012)/stdev(effort from 2003-2012).

Ecosystem Goal: Sustainability (for consumptive and non-consumptive uses)

Fish Stock Sustainability Index and Status of Groundfish, Crab, Salmon and Scallop Stocks

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Last updated: August 2013

Description of index: The Fish Stock Sustainability Index (FSSI) is a performance measure for the sustainability of fish stocks selected for their importance to commercial and recreational fisheries (`http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`). The FSSI will increase as overfishing is ended and stocks rebuild to the level that provides maximum sustainable yield. The FSSI is calculated by assigning a score for each fish stock based on the following rules:

1. Stock has known status determinations:
   (a) overfishing 0.5
   (b) overfished 0.5
2. Fishing mortality rate is below the "overfishing" level defined for the stock 1.0
3. Biomass is above the "overfished" level defined for the stock 1.0
4. Biomass is at or above 80% of the biomass that produces maximum sustainable yield (B_{MSY}) 1.0 (this point is in addition to the point awarded for being above the "overfished" level)

The maximum score for each stock is 4. There are 230 FSSI stocks in the U.S., with a maximum possible score of 920. The value of the FSSI is the sum of the individual stock scores. In the Alaska Region, there are 35 FSSI stocks and an overall FSSI of 140 would be achieved if every stock scored the maximum value, 4 (Tables 8 and 2). Additionally, there are 29 non-FSSI stocks, two ecosystem component species complexes, and Pacific halibut which are managed under an international agreement (Table 8 and 3).

Status and trends: As of June 30, 2013, no BSAI or GOA groundfish stock or stock complex is subjected to overfishing, and no BSAI or GOA groundfish stock or stock complex is considered to be overfished or to be approaching an overfished condition (Tables 8). The only crab stock considered to be overfished is the Pribilof Islands blue king crab stock, which is in the tenth year of a 10-year rebuilding plan. Of the non-FSSI stocks, only the BSAI octopus complex is subject to overfishing, and none are overfished or approaching an overfished condition (Table **??**).

The current overall Alaska FSSI is 122.5 out of a possible 140, based on updates through June 2013 (Table 9). The overall Bering Sea/Aleutian Islands score is 82 out of a possible maximum score of 92. The BSAI groundfish score is 54 (including BSAI/GOA sablefish, see Endnote-g in Box A) of a maximum possible 56 and BSAI king and tanner crabs score is 28 out of a possible 36. The Gulf of Alaska groundfish score is 40.5 of a maximum possible 48 (excluding BSAI/GOA sablefish). Overall, the Alaska total FSSI score is unchanged from 2012 to 2013 (Figure 71).

Table 8: Summary of status for FSSI and non-FSSI stocks managed under federal fishery management plans off Alaska, 2011.

Jurisdiction	Stock Group	Number of Stocks	Overfishing					Overfished				Approaching Over-fished Condi-tion
			Yes	No	Unk	Undef	NA	Yes	No	Unk	Undef	
NPFMC	FSSI	35	0	35	0	0	0	1	29	5	0	0
NPFMC	NonFSSI	29	1	28	0	0	0	0	4	25	0	0
	Total	64	1	63	0	0	0	1	33	30	0	0

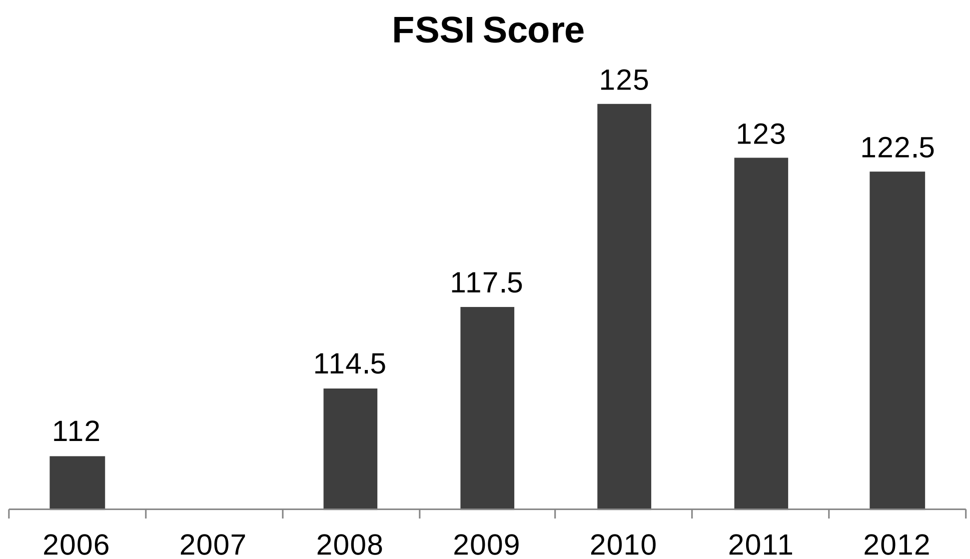

Figure 71: The trend in total Alaska FSSI from 2006 through 2013. All scores are reported through the second quarter (June) of each year, and are retrieved from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. The maximum possible FSSI score is 140 in all years.

Factors influencing observed trends: Though the total FSSI score held steady from 2012 to 2013, there were a few changes in how the points were awarded. Two points were gained for improvements with the Bering Sea southern tanner crab stock. One point was given for the stock biomass rising above the defined overfished biomass threshold and another point for the biomass being at or above 80% of BMSY. A point was lost for BSAI Greenland halibut biomass dropping below 80% of BMSY and another point was lost for the BSAI Blackspotted and Rougheye Rockfish complex for their biomass dropping below 80% of BMSY.

Groups in the BSAI region with FSSI scores less than 4 are golden king crab-Aleutian Islands (FSSI=1.5), red king crab-Pribilof Islands (FSSI=3), and red king crab-Western Aleutian Islands (FSSI=1.5). Both the golden king crab-Aleutian Islands and the red king crab-Western Aleutian Islands earn a half point for having a defined overfishing level and a whole point for having a fishing mortality rate that is below the defined overfishing level. These two stocks lose 2.5 points because the overfished status determination is not defined and it is therefore unknown if the biomass is above the overfished level or if biomass is at or above 80% of BMSY. The red king crab-Pribilof Islands stock loses a point because the biomass is below 80% of BMSY.

GOA stocks that had low FSSI scores (1.5) are the thornyhead rockfish complex (shortspine thornyhead rockfish as the indicator species), the demersal shelf rockfish complex (yelloweye rockfish as the indicator species), and the deepwater flatfish complex (no indicator species). The low scores of these groups are because the overfished status determination is not defined and it is therefore unknown if the biomass is above the overfished level or if biomass is at or above 80% of BMSY.

Implications: The majority of Alaska groundfish fisheries appear to be sustainably managed. A single stock is considered to be overfished (Pribilof Islands blue king crab), one stock is subject to overfishing (BSAI Octopus complex), and no stocks or stock complexes are approaching an overfished condition.

Table 9: FSSI stocks under NPFMC jurisdiction updated June 2013, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`.

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
Blue king crab - Pribilof Islands[a]	No	Yes	N/A	Rebuilding Program	Year 10 of 10	0.13	2
Blue king crab - Saint Matthews Island[b]	No	No	No	N/A	N/A	1.58	4
Golden king crab - Aleutian Islands	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Red king crab - Bristol Bay	No	No	No	N/A	N/A	0.96	4
Red king crab - Norton Sound	No	No	No	N/A	N/A	1.21	4
Red king crab - Pribilof Islands[c]	No	No	Unknown	N/A	N/A	0.64	3
Red king crab - Western Aleutian Islands	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Snow crab - Bering Sea	No	No	No	N/A	N/A	0.95	4
Southern Tanner crab - Bering Sea	No	No	No	N/A	N/A	1.28	4
BSAI Alaska plaice	No	No	No	N/A	N/A	1.94	4
BSAI Atka mackerel	No	No	No	N/A	N/A	1.16	4
BSAI Arrowtooth Flounder Complex	No	No	No	N/A	N/A	3.16	4
BSAI Blackspotted and Rougheye Rockfish[d]	No	No	No	N/A	N/A	0.71	3
BSAI Flathead Sole Complexe	No	No	No	N/A	N/A	2.17	4
BSAI Rock Sole Complex[f]	No	No	No	N/A	N/A	2.06	4
BSAI Greenland halibut	No	No	No	N/A	N/A	0.6	3
BSAI Northern rockfish	No	No	No	N/A	N/A	1.68	4
BSAI Pacific cod	No	No	No	N/A	N/A	1.18	4
BSAI Pacific Ocean perch	No	No	No	N/A	N/A	1.77	4
Walleye pollock - Aleutian Islands	No	No	No	N/A	N/A	0.96	4
Walleye pollock - Eastern Bering Sea	No	No	No	N/A	N/A	1.08	4
BSAI Yellowfin sole	No	No	No	N/A	N/A	1.53	4
BSAI GOA Sablefish[g]	No	No	No	N/A	N/A	1.06	4

Table 9: FSSI stocks under NPFMC jurisdiction updated June 2013, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. (continued)

Stock	Overfishing	Overfished	Approaching	Action	Progress	B/Bmsy	FSSI Score
GOA Arrowtooth flounder	No	No	No	N/A	N/A	2.99	4
GOA Flathead sole	No	No	No	N/A	N/A	2.87	4
GOA Blackspotted and Rougheye Rockfish complex[h]	No	No	No	N/A	N/A	1.48	4
GOA Deepwater Flatfish Complex[i]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
GOA Demersal Shelf Rockfish Complex[j]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
GOA Dusky Rockfish	No	No	No	N/A	N/A	1.57	4
GOA Thornyhead Rockfish Complex[k]	No	Unknown	Unknown	N/A	N/A	not estimated	1.5
Northern rockfish - Western / Central GOA	No	No	No	N/A	N/A	1.7	4
GOA Pacific cod	No	No	No	N/A	N/A	1.51	4
GOA Pacific Ocean perch	No	No	No	N/A	N/A	1.31	4
GOA Rex sole	No	No	No	N/A	N/A	2.74	4
Walleye pollock - Western / Central GOA	No	No	No	N/A	N/A	0.99	4

Box A. Endnotes and stock complex definitions for FSSI stocks listed in Table 9, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`.

(a) The NPFMC is revising the rebuilding plan for this stock, which will extend the rebuilding target date. In the meantime, there is no directed fishing for the blue king crab-Pribilof Islands and the majority of blue king crab habitat is closed to bottom trawling.

(b) Fishery in the EEZ is closed; therefore, fishing mortality is very low.

(c) Fishery in the EEZ is closed; therefore, fishing mortality is very low.

(d) BSAI Blackspotted and Rougheye Rockfish consists of Blackspotted Rockfish and Rougheye Rockfish. An assessment of the combined species provides the overfished determination, and the OFL is based on the combined-species assessment.

(e) Flathead Sole Complex consists of Flathead Sole and Bering Flounder. Flathead Sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species.

(f) Rock Sole Complex consists of Northern Rock Sole and Southern Rock Sole (NOTE: These are two distinct species, not two separate stocks of the same species). Northern Rock Sole accounts for the overwhelming majority of the biomass and is regarded as the indicator species for the complex. The overfished determination is based on the combined abundance estimates for the two species; the overfishing determination is based on the OFL, which is computed from the combined abundance estimates for the two species.

(g) Although Sablefish is managed separately in the Gulf of Alaska, Bering Sea, and Aleutian Islands, with separate overfishing levels, ABCs, and TACs based on the proportion of biomass in each respective region, separate assessments are not conducted for each of these three regions; the assessment is based on aggregated data from the Gulf of Alaska, Bering Sea, and Aleutian Islands regions. Therefore, it is not appropriate to list separate status determinations for these three regions.

(h) GOA Blackspotted and Rougheye Rockfish consists of Blackspotted Rockfish and Rougheye Rockfish. An assessment of the combined species provides the overfished determination, and the OFL is based on the combined-species assessment.

(i) The Deep Water Flatfish Complex consists of the following stocks: Deepsea Sole, Dover Sole, and Greenland Turbot. Prior to 2011, Dover sole was the indicator stock for the deep-water flatfish assemblage. However, the 2011 assessment contained a recommendation that the existing age-structured model be rejected, including using Dover sole as an indicator species. The deep-water flatfish complex therefore no longer has an indicator species and an overfished determination can no longer be made. The complex was not subject to overfishing in 2010.

(j) The Demersal Shelf Rockfish Complex consists of the following stocks: Canary Rockfish, China Rockfish, Copper Rockfish, Quillback Rockfish, Rosethorn Rockfish, Tiger Rockfish, and Yelloweye Rockfish. The overfishing determination is based on the OFL, which is computed by using estimates of Yelloweye Rockfish and then increased by 10% to account for the remaining members of the complex.

(k) The Thornyhead Rockfish Complex consists of the following stocks: Longspine Thornyhead and Shortspine Thornyhead. The overfishing determination is based on the OFL, which is computed using abundance estimates of Shortspine Thornyhead.

Table 10: Non-FSSI stocks, Ecosystem Component Species, and Stocks managed under an International Agreement updated June 2012, adapted from the Status of U.S. Fisheries website: `http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm`. See website for definition of stocks and stock complexes.

Stock	Jurisdiction	Overfishing	Overfished	Approaching
Golden king crab - Pribilof Islands	NPFMC	No	Undefined	Unknown
BSAI Octopus Complex	NPFMC	Unknown	Undefined	Unknown
BSAI Other Flatfish Complex	NPFMC	No	Undefined	Unknown
BSAI Other Rockfish Complex	NPFMC	No	Undefined	Unknown
BSAI Sculpin Complex	NPFMC	Unknown	Undefined	Unknown
BSAI Shark Complex	NPFMC	Unknown	Undefined	Unknown
BSAI Skate Complex	NPFMC	No	No	No
BSAI Squid Complex	NPFMC	No	Undefined	Unknown
BSAI Kamchatka flounder	NPFMC	Undefined	Undefined	Unknown
BSAI Shortraker rockfish	NPFMC	No	Undefined	Unknown
Walleye pollock - Bogoslof	NPFMC	No	Undefined	Unknown
GOA Atka mackerel	NPFMC	No	Undefined	Unknown
GOA Big skate	NPFMC	No	Undefined	Unknown
GOA Octopus complex	NPFMC	Unknown	Undefined	Unknown
GOA Squid Complex	NPFMC	Unknown	Undefined	Unknown
GOA Other Rockfish Complex	NPFMC	No	Undefined	Unknown
GOA Sculpin Complex	NPFMC	Unknown	Undefined	Unknown
GOA Shallow Water Flatfish Complex	NPFMC	No	No	No
GOA Shark Complex	NPFMC	Unknown	Undefined	Unknown
GOA Alaska skate Complex	NPFMC	No	Undefined	Unknown
GOA Longnose skate	NPFMC	No	Undefined	Unknown
GOA Shortraker rockfish	NPFMC	No	Undefined	Unknown
Walleye pollock - Eastern Gulf of Alaska	NPFMC	No	Undefined	Unknown
Alaska Coho Salmon Assemblage	NPFMC	No	No	No
Chinook salmon - E. North Pacific Far North Migrating	NPFMC	No	No	No
Weathervane scallop - Alaska	NPFMC	No	Undefined	Unknown
Arctic cod - Arctic FMP	NPFMC	No	Unknown	Unknown
Saffron cod - Arctic FMP	NPFMC	No	Unknown	Unknown
Snow crab - Arctic FMP	NPFMC	No	Unknown	Unknown
Ecosystem Component Species				
Fish resources of the Arctic mgmt. area - Arctic FMP	NPFMC	No	Unknown	Unknown
Scallop fishery off Alaska	NPFMC	Undefined	Undefined	N/A
Stocks managed under an International Agreement				
Pacific halibut - Pacific Coast / Alaska	IPHC/NP,PFMC	Undefined	No	No

Total Annual Surplus Production and Overall Exploitation Rate of Groundfish

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Last updated: July 2010

See the contribution archive at: `http://access.afsc.noaa.gov/reem/ecoweb/index.cfm`

Community Size Spectrum of the Bottom Trawl-Caught Fish Community of the Eastern Bering Sea

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Ecosystem Goal: Humans are part of ecosystems

Groundfish Fleet Composition

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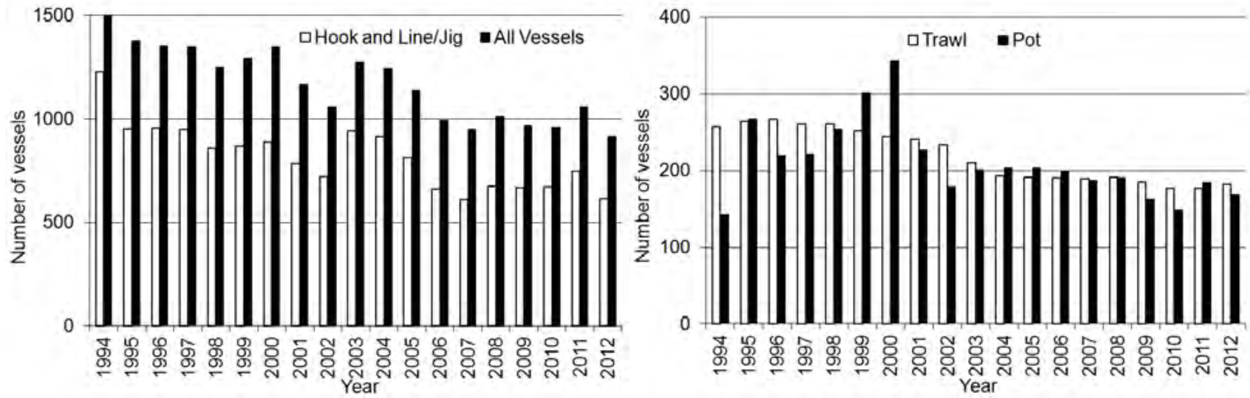
Description of index: Fishing vessels participating in federally-managed groundfish fisheries off Alaska principally use trawl, hook and line, and pot gear. Vessel counts in these tables were compiled from blend and Catch-Accounting System estimates and from fish ticket and observer data through 2012.

Status and trends: The pattern of changes in the total number of vessels harvesting groundfish and the number of vessels using hook and line gear have been very similar since 1994. Numbers have generally decreased since 1994 but have remained relatively stable in the last 5 years (2008-2012). The total number of vessels was 1,518 in 1994 and 917 in 2012 (Figure **??**). Hook and line/jig vessels accounted for about 1,225 and 614 of these vessels in 1994 and 2012, respectively. The number of vessels using trawl gear decreased from 257 in 1994 to 182 in 2012. During the same period, the number of vessels using pot gear peaked in 2000 at 343, and decreased to 168 in 2012.



(a) Hook and Line, All vessels (b) Trawl, Pot

Figure 72: Number of vessels participating in the groundfish fisheries off Alaska by gear type, 1994-2012.

Factors influencing observed trends: The increase in 2003 in the number of hook-and-line/jig and pot vessels (and, thus, also in the total number of vessels) results from replacement of the old blend system with the Catch-Accounting System (CAS) as the official estimates of groundfish catch. The new CAS data include the Federal Fisheries Permit numbers of catcher vessels delivering both to motherships and to shoreside processors, making possible a more complete count of participating vessels. It should be noted that vessel counts before and after 2003 are not directly comparable due to the change in data source mentioned above.

Implications: Monitoring the numbers of fishing vessels is important to fisheries managers because it provides general measures of fishing effort, the level of capitalization in the fisheries, and the potential magnitude of effects on industry stakeholders caused by management decisions.

Distribution and Abundance Trends in the Human Population of the Bering Sea/Aleutian Islands

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Description of index: Human population is a significant factor in GOA groundfish fishery management given the reliance of many communities in the region on fisheries to support their economies and historical subsistence needs. This report describes the distribution and abundance over time of human populations in Bering Sea/Aleutian Island (BSAI) fishing communities. Population was calculated by aggregating community level demographic data for selected Bering Sea communities for 1990, 2000 and 2010 (data from U.S. Census Bureau), and yearly between 2001and 2009 and 2011 (data from the Alaska Department of Labor and Workforce Development). This approach is concordant with research on arctic communities that uses crude population growth or loss as a

Table 11: Bering Sea and Aleutian Island fishing community populations

	1920	1990	2010	% change 1990-2010
Alaska	55,036	538,347	706,498	31.2
BSAI fishing communities	6,215	45,394	47,459	4.5
% Alaskan pop in BSAI fishing communities	11.3%	8.4%	6.7%	

general index of community viability (Aarsaether and Baerenholdt 2004).

The 91 Bering Sea and 8 Aleutian Islands fishing communities selected for use in this report comprise most of the population that lives along the coast of the Bering Sea and Aleutian Islands. Communities were selected if they were within 25 miles of the coast, and/or based on their historical involvement in BSAI subsistence or industrial fisheries. In addition, all Community Development Quota (CDQ) communities were included.

Status and trends: The overall population of BSAI fishing communities in 2010 was seven and a half times larger than its 1920 population - growing from 6,215 to 47,459. Overall population in the region grew 1.2% between 1990 and 2010. However, the proportion of people living in BSAI fishing communities relative to the total Alaskan population has declined from 11.3% in 1920 to 8.4% in 1990 and to 6.7% in 2010 (Table 11).

Nearly all of Alaska's rural areas, including BSAI, have had a positive average annual population growth rate since 2000 ; however, in the past decade these upward trends have been slowing. Seventy-six BSAI fishing communities (or 83.5%, not including seasonal use areas) have had a positive average annual percent change during the period between 2000 and 2010. Five communities showed between a zero and one percent average annual change over the same time period and 41 had a negative average annual percent change. Communities with a negative annual percent change during this time period appear to be concentrated in Aleutians East and West along with Lake and Peninsula and Bristol Bay Boroughs. The sharp decrease (seen above) in the Aleutians East and West area is largely due to the military base closure in Adak in 1997.

Overall, Alaska has one of the highest intra and interstate migration levels of any US state (Williams 2004). However, these figures differ dramatically across BSAI communities. Based on ADLWD 2004 statistics, Lake and Peninsula and Aleutians East and West exhibit some of the highest gross migration rates in Alaska (21 to 30% of the population) compared to the lowest rates of gross migration (9.5 - 11.9%) in Nome, Wade Hampton, and Bethel (Williams 2004a). In Aleutians West, which includes the region's major fishing hub in Unalaska/Dutch Harbor, only 25% of the residents were born in Alaska, compared to 94.1% in Wade Hampton.

Alaska has the highest share of indigenous Americans of any U.S. state (20%), and Alaska Natives made up 82% of the population in remote rural census areas, 90% when excluding regional hubs (Goldsmith et al. 2004). In 2010, in the BSAI, the percent Native population is lowest among the Aleutians East (27.9%) and Aleutians West (15.4%) and highest in Wade Hampton (95.0%) and Bethel (82.9%), though there is significant variation between communities. In 2009, Alaska Natives made up 78.8% (34,379 people) of the total population of the BSAI.

Factors influencing observed trends: The overall population growth in the BSAI region since 1920 reflects state and national trends, although the BSAI growth rate lags behind both. The two key factors affecting population growth rates are natural increase (birthrates subtracting mortality), and migration. Both factors affect the BSAI region.

High birth rates among Alaska Natives (50% higher than that of non-Natives) account for steady natural increase (births minus deaths) in many BSAI area populations (particularly Wade Hampton and Bethel), which serves to off-set out-migration from these areas. The Alaska version of the Todaro Paradox (Huskey et al. 2004) describes the out-migration of young Alaska Natives to urban centers for education and work opportunities, and the return migration to remote rural areas despite the high levels of unemployment there. This return migration is partly due to the social benefit of family networks, and the sustenance and income from subsistence activities which are most successful in natal villages where traditional environmental knowledge is an asset (Huskey et al. 2004).

Swift and dramatic changes in residency and migration patterns account for some of the region's population trends and anomalies. The military base closure in Adak accounts for Aleutians West population decline between 1992 and 1994. Historically, the gold mining industry accounted for community growth, decline, and in some cases abandonment (e.g., Council and Mary's Igloo) in the Nome area, while the fishing industry accounts for similar boom-bust dynamics in the Aleutians and Bethel, Dillingham, and Lake and Peninsula areas. An acute drop in ex-vessel prices for salmon has been the most significant driver of negative population growth in the latter two Census Areas in the last decade. Unlike many other parts of the state, the oil and gas industry has not been a direct factor in BSAI population dynamics.

Implications: Given that many Alaska Natives are traditionally dependent on harvesting marine resources for subsistence purposes and the high percentage of the BSAI population that considers themselves Alaska Native, it is not surprising that roughly 61% of salmon, 43% of non-salmon, 95% of walrus, and 86% of beluga whales taken for subsistence purposes in the state of Alaska are harvested by BSAI residents (ABWC 2011, ADFG 2011). The regions reliance on the subsistence harvest of salmon is crucial as fisheries managers consider regulations for commercial groundfish fishing, especially given recent tensions surrounding bycatch of chum and Chinook salmon in commercial fisheries in the Bering Sea. In addition, over a third of BSAI fishing communities are highly dependent on the subsistence harvest of ice seals. As the Alaska Native population in this region expands, contracts and shifts around the Bering Sea, individual communities' reliance on salmon and other marine resources for subsistence will play heavily into the overall fishing pressure on all species harvested in the Bering Sea, including the commercial groundfish fishery.

Population decline or growth can affect community and regional specific pressures on fisheries resources. As populations throughout the BSAI expand and contract, so will pressures on groundfish resources. In 2011, 99 groundfish license limitation program (LLP) permits were fished by BSAI residents, representing 27% of all these permits fished by Alaska residents. In addition, approximately 1.26 billion pounds or 74% of all groundfish were landed in BSAI communities, thus contributing almost $233 million to the BSAI economy or 5% of the value of all groundfish landings at shore-based processors in the state (CFEC 2011).

Finally, population decline or growth in small communities can factor into health care provision, education, land use, environmental impacts, transportation, and other social services (Williams 2004a). Over 36% of federal dollars allocated to Alaska depend in some way on population, State programs attach many services to population, and CDQ quota shares are also provisioned in relation to population numbers. As an example, the CDQ entities distribute revenue from leasing and harvesting CDQ quota shares and provide CDQ funded programs and services to the 65 CDQ com-

Table 12: Gulf of Alaska (GOA) fishing community populations

	1920	1990	2010	% change 1990-2010
Alaska	55,036	538,347	692,314	28.6
Anchorage	na	226,338	291,826	28.9
GOA fishing communtities (incl. Anchorage)	18,533	345,230	447,134	29.5
GOA fishing communtities (excl. Anchorage)	na	118,892	150,292	12.6

munities in Western Alaska. Any changes to fisheries management programs that affect the overall revenue gained through the CDQ program could drastically affect the welfare of the population of those communities.

Distribution and Abundance Trends in the Human Population of the Gulf of Alaska

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Description of index: Human population is a significant factor in GOA groundfish fishery management given the reliance of many communities in the region on fisheries to support their economies and historical subsistence needs. This report describes the distribution and abundance over time of human populations in the Gulf of Alaska (GOA) (including Southeast Alaska, Cook Inlet, and Prince William Sound). Population in the region was calculated by aggregating community level demographic data for 1990, 2000 and 2010 (U.S. Census Bureau 2011), and yearly between 2001 and 2009 (Alaska Department of Labor and Workforce Development 2011). This approach is concordant with research on arctic communities that uses crude population growth or loss as a general index of community viability (Aarsaether and Baerenholdt 2004).

The 105 GOA fishing communities selected for use in this report comprise most of the population that lives along the coast of the Gulf of Alaska. Communities were selected if they were within 25 miles of the coast, and/or based on their historical involvement in Gulf of Alaska subsistence or industrial fisheries, or if they were included in one of the North Pacific Fishery Management Council's GOA fishery programs, such as the Community Quota Entity program.

Status and trends: The proportion of people living in GOA fishing communities relative to the total Alaskan population has increased from around 34% in 1920 to 64.1% in 2009 (Table 1). The vast majority of the growth occurred in the city of Anchorage after 1950. Between 1990 and 2009, its population grew by 28.4%.

The overall population of GOA fishing communities (excluding Anchorage) in 2010 was 241 times larger than its 1920 population (Table 12). However, 57% of the communities experienced an average annual decline between 2000 and 2009. According to the U.S. Census Bureau, populations decreased to zero or near zero in 2010 for Annette Island, Whitestone logging camp, Cube Cove, Hobart Bay, Meyers Chuck and Thoms Place.

Alaska currently has the highest share of indigenous Americans of any U.S. state (20%). Alaska Natives made up 82% of the population of the remote rural Census Areas, 90% when excluding regional hubs (Goldsmith et al. 2004). According to the U.S. Census Bureau, in 2010, Alaska Natives made up 28% of the total population in the GOA, when excluding the population of Anchorage (9.5% if the Anchorage population is included).

Alaska has one of the highest population concentrations in the United States with 66% of its population currently concentrated in Anchorage. New York and Hawaii have the most similar population concentrations with 42.9% in New York City and 28.9% in Honolulu. With respect to distance from the nearest major American city, Anchorage (1432 miles to Seattle) is second only to Honolulu (2554 miles to Los Angeles).

Factors influencing observed trends: The overall population growth in the GOA region from 1990 to 2009 reflects state and national trends. The GOA population growth rate (28.6%) lags slightly behind state trends (25.9%) and is ahead of national trends (23.4%). The two key factors affecting these population growth rates are natural increase (births minus deaths) and migration. Except for the Matanuska-Susitna Borough, every area with positive population growth saw their natural increase outstrip their net migration between 2000 and 2004 (Williams 2006). Birth rates in the state were lowest in the Aleutian chain and in Southeast Alaska between 2000 and 2004.

Changes in patterns of natural resource extraction and military presence explain many of the recent population trends in the GOA. Cut-backs in the Coast Guard account for Kodiak's population decline in the 1990s (Williams 2006). The fishing industry accounted for community growth, decline, and in some cases abandonment in the Aleutians, Lake and Peninsula, and Kodiak areas. The Aleutians East gained population at this time because of the movement of a substantial amount of groundfish processing on shore (Williams 2004), while the population in Pelican declined 55% in part due to the closure of a processing plant. Other fishing communities, specifically those most dependent on salmon, were impacted by a sharp decline in ex-vessel prices. A loss of timber harvesting and wood processing jobs in the 1990s led to major population decreases in some Southeast communities, including Whitestone Logging Camp, which declined from 164 to 0 between 1990 and 2006, but has since increased to a population of 17 in 2010. Historically, the sharp increase in Anchorage's population began with the military buildup during and after WWII, but it was oil development beginning in the late 1970s that fueled unprecedented growth.

Implications: Population decline or growth can affect community and regional specific pressures on fisheries resources. As populations throughout the GOA expand and contract, so will pressures on groundfish resources. In 2009, 596 actively fished groundfish license limitation program (LLP) permits were held by GOA residents, representing 96.6% of all these permits issued to Alaska residents. In addition, in 2011, approximately 433.1 million pounds of groundfish were landed in GOA communities, thus contributing almost $201.6 million to the GOA economy or 46% of the value of all groundfish landings at shore-based processors in the state. Based on how population across GOA communities changes, changes in groundfish management could have implications for the stability of both regional and individual community economies.

Furthermore, the concentration of a state's population in a single city, Anchorage, concentrates goods, services, trade, and travel routes in one place. The concentrated population also allows for services (e.g., medical treatment, business and technology support, entertainment) that would not otherwise be sustainable in the state and attracts people to the area due to increased employment and education opportunities. The population growth and concentration in Anchorage has also had negative impacts on the surrounding area through sprawl into the Matanuska-Susitna valley, increased regional hunting and fishing pressures and lower take allowed per capita, increased recreation demand, and loss of agricultural land due to high speculative land values (Fischer 1976).

References

Anderson, P. J. 2003. Gulf of Alaska small mesh trawl survey trends, In: J.L.Boldt (Ed.), Ecosystem Considerations for 2004. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Reports. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Atwood, E., J. K. Duffy-Anderson, J. K. Horne, and C. Ladd. 2010. Influence of mesoscale eddies on ichthyoplankton assemblages in the Gulf of Alaska. Fisheries Oceanography **19**:493–507.

AVISO. 2012. Map of sea level anomalies.

Baier, C. T., and J. M. Napp. 2003. Climate-induced variability in Calanus marshallae populations. Journal of Plankton Research **25**:771–782.

Beamish, R. J., C. Neville, R. Sweeting, and K. Lange. 2012. The Synchronous Failure of Juvenile Pacific Salmon and Herring Production in the Strait of Georgia in 2007 and the Poor Return of Sockeye Salmon to the Fraser River in 2009. Marine and Coastal Fisheries **4**:403–414.

Beamish, R. J., R. M. Sweeting, and C. M. Neville. 2004. Improvement of Juvenile Pacific Salmon Production in a Regional Ecosystem after the 1998 Climatic Regime Shift. Transactions of the American Fisheries Society **133**:1163–1175.

Bond, N. A., and L. Guy. 2010. North Pacific Climate Overview In: S. Zador and S. Gaichas (Ed.), Ecosystem Considerations for 2010. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Report. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Brickley, P. J., and A. C. Thomas. 2004. Satellite-measured seasonal and inter-annual chlorophyll variability in the Northeast Pacific and Coastal Gulf of Alaska. Deep-Sea Research Part Ii-Topical Studies in Oceanography **51**:229–245.

Brodeur, R., and D. M. Ware. 1992. Long-term variability in zooplankton biomass in the subarctic Pacific Ocean. Fisheries Oceanography **1**:32–37.

Cahalan, J., J. Mondragon, and J. Gasper. 2010. Catch sampling and estimation in the Federal groundfish fisheries off Alaska. Technical report, U.S. Dep. Commer., NOA Tech. Memo. NMFS-AFSC-205, 42 p.

Condon, R. H., D. K. Steinberg, P. A. del Giorgio, T. C. Bouvier, D. A. Bronk, W. M. Graham, and H. W. Ducklow. 2011. Jellyfish blooms result in a major microbial respiratory sink of carbon in marine systems. Proceedings of the National Academy of Sciences **108**:10225–10230.

Cooney, R. T., and T. M. Willette. 1997. Factors influencing the marine survival of pink salmon in Prince William Sound, Alaska. In: (Emmett, R. L. and Schiewe, M. H.) Estuarine and ocean survival of northeastern Pacific salmon. NOAA Tech Memo NMFS-NWFSC-29 .

Coyle, K. O., L. Eisner, F. J. Mueter, A. Pinchuk, M. Janout, K. Cieciel, E. Farley, and A. Andrews. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the Oscillating Control Hypothesis. Fisheries Oceanography **20**:139–156.

Di Lorenzo, E., J. Fiechter, N. Schneider, A. Bracco, A. J. Miller, P. J. S. Franks, S. J. Bograd, A. M. Moore, A. C. Thomas, W. Crawford, A. Pea, and A. J. Hermann. 2009. Nutrient and salinity decadal variations in the central and eastern North Pacific. Geophysical Research Letters **36**:L14601.

Di Lorenzo, E., N. Schneider, K. M. Cobb, P. J. S. Franks, K. Chhak, A. J. Miller, J. C. McWilliams, S. J. Bograd, H. Arango, E. Curchitser, T. M. Powell, and P. Riviere. 2008. North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophysical Research Letters **35**.

Dietrich, K. S., and E. F. Melvin. 2008. Alaska Trawl Fisheries: Potential Interations with North Pacific Albatrosses. Technical report, Washington Sea Grant.

Downton, M. W., and K. A. Miller. 1998. Relationships between Alaskan salmon catch and North Pacific climate on interannual and interdecadal time scales. Canadian Journal of Fisheries and Aquatic Sciences **55**:2255–2265.

Doyle, M. J., S. J. Picquelle, K. L. Mier, M. Spillane, and N. bond. 2009. Larval fish abundance and physical forcing in the Gulf of Alaska, 1981-2003. Progress in Oceanography **80**:163–187.

Ducet, N., P. Y. Le Traon, and G. Reverdin. 2000. Global high-resolution mapping of ocean circulation from TOPEX/Poseidon and ERS-1 and-2. Journal of Geophysical Research-Oceans **105**:19477–19498.

Eggers, D. M., C. Tide, and A. M. Carroll. 2013. Run Forecasts and Harvest Projections for 2013 Alaska Salmon Fisheries and Review of the 2012 Season.

Fair, L. 2003. Bristol Bay sockeye salmon. In (Eggers, D. M.) Run Forecasts and Harvest Projections for 2003 Alaska Salmon Fisheries and Review of the 2002 Season. Juneau: Alaska Department of Fish and Game Regional Information Report No. 5J03-01. .

Farley, E., J. Moss, and R. Beamish. 2007. A Review of the critical size, critical period hypothesis for juvenile Pacific salmon. North Pacific Anadromous Fish Commission Bulletin **4**:311–317.

Fergusson, E. A., M. V. Sturdevant, and J. A. Orsi. 2013. Trophic relationships among juvenile salmon during a 16-year time series of climate variability in Southeast Alaska. Technical report.

Fitzgerald, S., M. Perez, and K. Rivera. 2008. Summary of Seabird Bycatch in Alaskan Groundfish Fisheries, 1993 through 2006. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Francis, R. C., S. R. Hare, A. B. Hollowed, and W. S. Wooster. 1998. Effects of interdecadal climate variability on the oceanic ecosystems of the NE Pacific. Fisheries Oceanography **7**:1–21.

Hare, S. R., and N. J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Progress in Oceanography **47**:103–145.

Heintz, R., E. Farley, and E. Siddon. 2010. Fall Condition of YOY Predicts Recruitment of Age-1 Walleye Pollock. In: Zador and Gaichas (Eds.), Ecosystem Considerations for 2011. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Reports. Technical report, North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Heintz, R. A., E. C. Siddon, E. V. Farley Jr, and J. M. Napp. 2013. Correlation between recruitment and fall condition of age-0 pollock (Theragra chalcogramma) from the eastern Bering Sea under varying climate conditions. Deep Sea Research Part II: Topical Studies in Oceanography .

Hilborn, R., T. P. Quinn, D. E. Schindler, and D. E. rogers. 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences of the United States of America **100**:6564–6568.

Hunt, G. L., K. O. Coyle, L. Eisner, E. Farley, R. Heintz, F. J. Mueter, J. M. Napp, J. E. Overland, P. Ressler, S. A. Salo, and P. Stabeno. 2011. Climate impacts on eastern Bering Sea food webs: A synthesis of new data and an assessment of the Oscillating Control Hypothesis. Ices Journal of Marine Science **68**:1230–1243.

Hunt, G. L., P. Stabeno, G. Walters, E. Sinclair, R. D. Brodeur, J. M. Napp, and N. A. Bond. 2002. Climate change and control of the southeastern Bering Sea pelagic ecosystem. Deep-Sea Research Part Ii-Topical Studies in Oceanography **49**:5821–5853.

Ianelli, J. N., T. Honkalehto, S. Barbeaux, S. Kotwicki, K. Y. Aydin, and N. Williamson. 2012. Assessment of the walleye pollock stock in the Eastern Bering Sea. Technical report, N Pac Fish Manage Council, 605 W 4th Ave, Anchorage, AK 99510.

King, J. 2005. Report of the Study Group on Fisheries and Ecosystem Responses to recent regime shifts. PICES Scientific Report No. 28. Technical report.

Kline, J., T. C. 2010. Stable carbon and nitrogen isotope variation in the northern lampfish and Neocalanus, marine survival rates of pink salmon, and meso-scale eddies in the Gulf of Alaska. Progress in Oceanography **87**:49–60.

Kline, T. C., J. Boldt, E. Farley, L. J. Haldorson, and J. H. Helle. 2008. Pink salmon (Oncorhynchus gorbuscha) marine survival rates reflect early marine carbon source dependency. Progress in Oceanography **77**:194–202.

Kooka, K., O. Yamamura, A. Nishimura, T. Hamatsu, and T. Yanagimoto. 2007. Optimum temperature for growth of juvenile walleye pollock Theragra chalcogramma. Journal of Experimental Marine Biology and Ecology **347**:69–76.

Ladd, C. 2007. Interannual variability of the Gulf of Alaska eddy field. Geophysical Research Letters **34**.

Ladd, C., W. R. Crawford, C. Harpold, W. Johnson, N. B. Kachel, P. Stabeno, and F. Whitney. 2009. A synoptic survey of young mesoscale eddies in the Eastern Gulf of Alaska. Deep-Sea Research Part II **56**:2460–2473.

Ladd, C., N. B. Kachel, C. W. Mordy, and P. J. Stabeno. 2005. Observations from a Yakutat eddy in the northern Gulf of Alaska. Journal of Geophysical Research-Oceans **110**.

Ladd, C., C. W. Mordy, N. B. Kachel, and P. J. Stabeno. 2007. Northern Gulf of Alaska eddies and associated anomalies. Deep-Sea Research Part I-Oceanographic Research Papers **54**:487–509.

Link, J. S., J. K. T. Brodziak, S. F. Edwards, W. J. Overholtz, D. Mountain, J. W. Jossi, T. D. Smith, and M. J. Fogarty. 2002. Marine ecosystem assessment in a fisheries management context. Canadian Journal of Fisheries and Aquatic Sciences **59**:1429–1440.

Mackas, D. L., W. Greve, M. Edwards, S. Chiba, K. Tadokoro, D. Eloire, M. G. Mazzocchi, S. Batten, A. J. Richardson, C. Johnson, E. Head, A. Conversi, and T. Peluso. 2012. Changing zooplankton seasonality in a changing ocean: Comparing time series of zooplankton phenology. Progress in Oceanography **97100**:31–62.

Mackas, D. L., W. T. Peterson, and J. E. Zamon. 2004. Comparisons of interannual biomass anomalies of zooplankton communities along the continental margins of British Columbia and Oregon. Deep Sea Research Part II: Topical Studies in Oceanography **51**:875–896.

Martinson, E. C., H. H. Stokes, and D. L. Scarnecchia. 2012. Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0yr class strengths in the Gulf of Alaska and eastern Bering Sea. Fisheries Oceanography **21**:307–319.

Maslowski, W., R. Roman, and J. C. Kinney. 2008. Effects of mesoscale eddies on the flow of the Alaskan Stream. Journal of Geophysical Research-Oceans **113**.

Matarese, A. C., D. M. Blood, S. J. Picquelle, and J. L. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). Technical report.

Mordy, C. W., P. J. Stabeno, C. Ladd, S. Zeeman, D. P. Wisegarver, S. A. Salo, and G. L. Hunt. 2005. Nutrients and primary production along the eastern Aleutian Island Archipelago. Fisheries Oceanography **14**:55–76.

NMFS. 2007. Conservation Plan for the eastern Pacific stock of Northern fur seal (*Callorhinus ursinus*). December 2007. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NMFS Protected Resources Division, Alaska Region. 137 pp. `http://www.fakr.noaa.gov/protectedresources/seals/fur/cplan/final1207.pdf` .

Okkonen, S. R. 1996. The influence of an Alaskan Stream eddy on flow through Amchitka Pass. Journal of Geophysical Research-Oceans **101**:8839–8851.

Okkonen, S. R., G. A. Jacobs, E. J. Metzger, H. E. Hurlburt, and J. F. Shriver. 2001. Mesoscale variability in the boundary currents of the Alaska Gyre. Continental Shelf Research **21**:1219–1236.

Okkonen, S. R., T. J. Weingartner, S. L. Danielson, D. L. Musgrave, and G. M. Schmidt. 2003. Satellite and hydrographic observations of eddy-induced shelf-slope exchange in the northwestern Gulf of Alaska. Journal of Geophysical Research-Oceans **108**.

Orsi, J., A. Wertheimer, M. Sturdevant, E. Fergusson, D. Mortensen, and B. Wing. 2004. Juvenile chum salmon consumption of zooplankton in marine waters of southeastern Alaska: a bioenergetics approach to implications of hatchery stock interactions. Reviews in Fish Biology and Fisheries **14**:335–359.

Orsi, J. A., M. Sturdevant, and E. Fergusson. 2013. Connecting the dots? among coastal ocean metrics and Pacific salmon production in Southeast Alaska, 1997-2012. Technical report.

Ortiz, I., F. Weise, and A. Grieg. in press. Marine regions in the Bering Sea. Deep Sea Research II .

Park, W., M. V. Sturdevant, J. A. Orsi, A. Wertheimer, E. A. Fergusson, W. R. Heard, and T. Shirley. 2004. Interannual abundance patterns of copepods during an ENSO event in Icy Strait, southeastern Alaska. Ices Journal of Marine Science **61**:464–477.

Piatt, J. F., and P. J. Anderson. 1996. Response of Common Murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. American Fisheries Society Symposium **18**:720–737.

Purcell, J. E., R. A. Hoover, and N. T. Schwarck. 2009. Interannual variation of strobilation by the scyphozoan Aurelia labiata in relation to polyp density, temperature, salinity, and light conditions in situ. Marine Ecology Progress Series **375**:139–149.

Ream, R. R., J. T. Sterling, and T. R. Loughlin. 2005. Oceanographic features related to northern fur seal migratory movements. Deep-Sea Research Part Ii-Topical Studies in Oceanography **52**:823–843.

Richardson, A. J., A. W. Walne, A. G. J. John, T. D. Jonas, J. A. Lindley, D. W. Sims, D. Stevens, and M. Witt. 2006. Using continuous plankton recorder data. Progress in Oceanography **68**:27–74.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers, and M. S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. Nature **465**:609–613.

Siddon, E. C., R. A. Heintz, and F. J. Mueter. 2013. Conceptual model of energy allocation in walleye pollock (Theragra chalcogramma) from age-0 to age-1 in the southeastern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography .

Spalinger, K. 2013. Bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2012. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Management Report No. 13-27, Anchorage. Technical report.

Stabeno, P. J., D. G. Kachel, N. B. Kachel, and M. E. Sullivan. 2005. Observations from moorings in the Aleutian Passes: temperature, salinity and transport. Fisheries Oceanography **14**:39–54.

Sturdevant, M. V., R. Brenner, E. A. Fergusson, J. A. Orsi, and B. Heard. 2013. Does predation by returning adult pink salmon regulate pink salmon or herring abundance? Technical report.

Sturdevant, M. V., J. A. Orsi, and E. A. Fergusson. 2012. Diets and Trophic Linkages of Epipelagic Fish Predators in Coastal Southeast Alaska during a Period of Warm and Cold Climate Years, 19972011. Marine and Coastal Fisheries **4**:526–545.

Weingartner, T., L. Eisner, G. L. Eckert, and S. Danielson. 2009. Southeast Alaska: oceanographic habitats and linkages. Journal of Biogeography **36**:387–400.

Wespestad, V. G., L. W. Fritz, W. J. Ingraham, and B. A. Megrey. 2000. On relationships between cannibalism, climate variability, physical transport, and recruitment success of Bering Sea walleye pollock (Theragra chalcogramma). Ices Journal of Marine Science **57**:272–278.

Wilderbuer, T. K., A. B. Hollowed, W. J. Ingraham, P. D. Spencer, M. E. Conners, N. A. Bond, and G. E. Walters. 2002. Flatfish recruitment response to decadal climatic variability and ocean conditions in the eastern Bering Sea. Progress in Oceanography **55**:235–247.

Willette, T. M., and R. T. Cooney. 1991. An empirical orthogonal functions analysis of sea surface temperature anomalies in the North Pacific Ocean and cross correlations with pink salmon (*Oncorhynchus gorbuscha*) returns to southern Alaska. In: (White, B., and Guthrie, I.) Proceedings of 15th Pink and Chum Salmon Workshop. Pacific Salmon Commission pages 111–121 .

Witherell, D., and Woodby. 2005. Application of marine protected areas for sustainable production and marine biodiversity off Alaska. Marine Fisheries Review **67**:1.

Wolter, K. 2012. Multivariate ENSO Index (MEI).

Zador, S. G. 2012. Ecosystem Considerations 2012. Technical report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Zwolinski, J., and D. A. Demer. 2012. A cold oceanographic regime with high exploitation rates in the Northeast Pacific forecasts a collapse of the sardine stock. Proceedings of the National Academy of Sciences **109**:4175–4180.